THE COUNTRY OF THE IGUANODON, RESTORED BY JOHN MARTIN, ESQ. K.L.

THE

WONDERS OF GEOLOGY;

OR,

A FAMILIAR EXPOSITION

OF

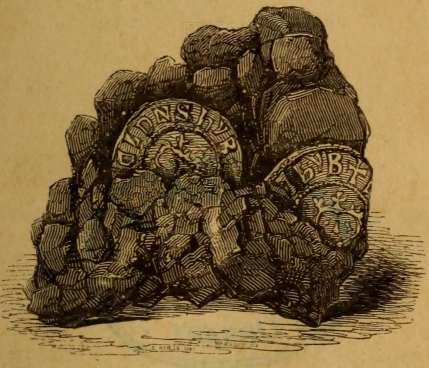
Geological Phenomena.

BY

GIDEON ALGERNON MANTELL, LL.D. F.R.S.

HONORARY FELLOW OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND, ETC.

AUTHOR OF THE MEDALS OF CREATION, THOUGHTS ON ANIMALCULES, ETC.



Silver Coins of Edward the First, imbedded in ironstone.—Page 82

"My heart is awed within me, when I think
Of the great miracle which still goes on
In silence round me—the perpetual work
Of Thy creation, finished, yet renewed
For ever!"

IN TWO VOLUMES.—VOL. I.

SIXTH EDITION.

LONDON:
HENRY G. BOHN, YORK STREET, COVENT GARDEN.
1848.

LONDON:
R. CLAY, PRINTER, BREAD STREET HILL.

TO

BENJAMIN SILLIMAN, Esq. LL.D. M.D.

PROFESSOR OF CHEMISTRY AND GEOLOGY IN YALE COLLEGE,

NEWHAVEN, CONNECTICUT;

FOUNDER AND EDITOR OF THE AMERICAN JOURNAL OF SCIENCE;

FOREIGN MEMBER OF THE GEOLOGICAL SOCIETY OF LONDON;

ETC. ETC.

My very dear Friend,

It is with the liveliest pleasure that I inscribe anew "The Wonders of Geology" with your distinguished name: for although we have never met—and probably never shall meet in this world—a friendship originating in mutual respect and regard, and cemented by an unrestricted correspondence, and an unreserved interchange of thought and feeling, for nearly twenty years, needs not the aid of personal intercourse to increase its ardour, or ensure its permanence.

That you may long be spared for the advancement of the Sciences you have so successfully cultivated and promoted—and for the benefit of your countrymen whose national character your labours have so greatly contributed to elevate and refine—and for the delight of a large domestic circle by whom you are alike respected and beloved—is the fervent prayer of

Your much attached friend,

GIDEON ALGERNON MANTELL.

19, CHESTER SQUARE, PIMLICO;
London, Jan. 1848.

ADVERTISEMENT.

Although but a few years have elapsed since the last edition of these volumes issued from the press, the great advancement of Geology and the collateral Sciences rendered it necessary to compose the entire work anew, that the most important recent discoveries in Palæontology, and the new or modified views of geological phenomena resulting from the progress of knowledge, might be incorporated in the respective Lectures.

The time and labour required for the preparation of the present edition have, therefore, been considerable; and since, like all my former works, these volumes have been composed in the intervals of arduous professional avocations, I venture to claim indulgence for any inaccuracies, repetitions, or omissions.

I would especially entreat the favourable consideration of any author whose statements or opinions may appear in the following pages without reference, or due acknowledgment; for, in the multiplicity of subjects comprised in this edition, I am apprehensive that I may, in some instances, have inadvertently stated as original, ideas and suggestions, unconsciously derived from the works of others.

The style and arrangement of the Lectures have been retained, as it appeared inexpedient to alter the plan of a work of which ten thousand copies have been issued, and which has been republished in America, and translated into German by an eminent Professor of the University of Bonn.

To render these volumes available to the purchasers of "The Medals of Creation," a table of the references to the "Wonders of Geology" in that work, corrected for this edition, is annexed; for the two works are intended to illustrate each other; the present volumes offering a familiar exposition of the *Philosophy of Geology*, and The Medals a compendious view of the *Principles of Palæontology.*

19, Chester Square,
Pimlico.

PREFACE

TO THE FORMER EDITION.

A course of Lectures delivered at Brighton, in an unsuccessful attempt to establish in that town a public museum, illustrative of the Geology, and Organic Remains, of the South-East of England, formed the groundwork of the unpretending volumes which, under the title of "The Wonders of Geology," have met with so favourable a reception.

When the first edition appeared, my collection, consisting of upwards of 20,000 specimens, from which the subjects for the illustrations of the Lectures were selected, was exhibited at Brighton, by the Sussex Literary Institution, as the *Mantellian Museum*, with the view to its permanent establishment as the basis of a County Museum.

That expectation was, however, defeated; for though I would willingly have made any pecuniary sacrifice, to accomplish what appeared to me so desirable an object, yet after the death of my noble and lamented friend, the late Earl of Egremont, the munificent patron of the Institution,—and of the Earl of Munster, who was an ardent supporter of the measure,—the plan was abandoned, in consequence of the lukewarmness, and even opposition, of some of those who had engaged to carry out the object. I therefore, in compliance with the suggestions of my scientific friends, disposed of the entire collection to the Trustees of the British Museum.

But although the main object of my labours was thus frustrated, and the collection,—which would have been of tenfold importance if located in the district whence it was derived, and whose geological structure it was designed to illustrate,—is now broken up, and dispersed through the cabinets of our National Institution, yet many of the most interesting organic remains are so unique, and so strikingly distinct from any other specimens hitherto obtained, that they may be referred to with facility, when the gallery of Organic Remains in the British Museum shall be finally arranged.*

I avail myself of this opportunity to record the deep sense of obligation I feel to many excellent friends, for

* As, for example, the remains of the Wealden reptiles, the Iguanodon, Hylæosaurus, Cetiosaurus, Swanage Crocodile, &c.; the Fishes from the Chalk, &c.

their strenuous and unremitting exertions to prevent the dispersion of my Museum, and to establish it on a permanent basis in my native County. And although their efforts have proved unavailing, a time will assuredly come, when their endeavours to promote a taste for scientific knowledge among the intelligent inhabitants of Sussex will be duly appreciated, and the failure of the attempt to secure to the County a collection so rich in its peculiar fossil and mineral productions, be remembered with regret.

At the suggestion of the eminent publisher with whose imprint the work now appears, the Introduction by Professor Silliman, appended to the American, is prefixed to the present edition.

G. A. M.

ADDRESS TO THE READER.

Geology, beyond almost every other science, offers fields of research adapted to all capacities, and to every condition and circumstance in life in which we may be placed. For while some of its phenomena require the highest intellectual powers, and the greatest attainments in abstract science, for their successful investigation, many of its problems may be solved by the most ordinary intellect, and facts replete with the deepest interest may be gleaned by the most casual observer.

To the medical philosopher Geology presents peculiar attractions for those hours of leisure and relaxation, which are indispensable to maintain a healthy state of mind; for it requires the cultivation and application of Chemistry, Botany, Comparative Anatomy, Zoology, and Physiology,—sciences which form the very foundation of medical knowledge. It exerts, too, the most salutary influence, by calling forth the continual exercise of our intellectual powers; for the desire to explain what is obscure in the natural records of the past, induces a more accurate examination of existing physical phenomena, and of the organization and habits of the living beings within the reach of actual observation. It enforces the necessity of weighing the conflicting evidence of apparently irreconcilable phenomena, of detecting differences, and seeking analogies, and of generalizing and combining an immense number of isolated facts. The mind thus acquires the power of acute observation, of patient investigation, and of salutary caution in drawing inferences, and arriving at conclusions — habits of the first importance in the discrimination and treatment of diseases.

And however little, in the present state of the public mind, such qualities may be appreciated, the labour will bring an ample reward in the self-conviction that the talents entrusted to us have not been given in vain.

> "Better than Fame is still the toil for Fame,
> The constant training for the glorious strife!"

For it should ever be borne in mind that the primary object of every study ought to be an inward one—that of enlarging and elevating the intellect; and the direct aim of science should be the discovery of the principles of unity, order, and connexion, which are everywhere manifest in the universal life of nature.

In proof that intellectual pursuits of the highest order are not incompatible with any situation in life, I would earnestly solicit attention to the following eloquent appeal by one of the most enlightened statesmen of our times:—

"Heed not the sneers and foolish sarcasms against learning, of those who are unwilling that you should rise above the level of their own contented ignorance. Do not for a moment imagine that you have not time for acquiring knowledge; it is only the idle man who wants time for every thing. The industrious man knows the inestimable value of the economy of time, and amidst the most multifarious occupations, can find leisure for rational recreation, and mental improvement. Do not believe that the acquisition of scientific knowledge will obstruct your worldly prosperity, or that it is incompatible with your worldly pursuits. Rely upon it, you cannot sharpen your intellectual faculties, you cannot widen the range of your knowledge, without becoming more skilful and successful in the business or profession in which you are engaged."*

I may add, that by that happy connexion, whereby the useful is indissolubly linked with the true, the exalted, and the beautiful, science thus followed for its own sake, will pour forth abundant overflowing streams to enrich and fertilize that industrial prosperity, which is the conquest of the intelligence of Man over matter.†

* Inaugural Address at the opening of the Tamworth Institution, 1841, by the Right Hon. Sir Robert Peel, Bart.

† See Introduction to Cosmos, or a Sketch of a Physical Description of the Universe; by Alexander Von Humboldt.

TABLE OF CONTENTS.

VOL. I.

VOL. II.

THE

WONDERS OF GEOLOGY.

INTRODUCTION TO THE AMERICAN EDITION,

BY

PROFESSOR SILLIMAN.

1. Object of the Science.—Geology is the natural history of the earth; its hills and mountains, its rivers, lakes, seas, and oceans, its fertile plains and sterile deserts—in a word, all that belongs to physical geography, is comprised in this science. Incidentally, it takes notice of agriculture and commerce, of the various improvements of civilization, and of the races and families of animated beings of both organic kingdoms, since they are all influenced, more or less, by geological phenomena. Every thing upon the globe is, therefore, connected with geology, which embraces likewise the principal physical facts and events of which our planet has been the theatre.

But the more immediate object of this science is to ascertain the structure of the earth, and the nature of the masses of which its crust is composed—the order of their arrangement—their mineral and organic contents—the proximate causes by which they were formed and deposited, and those by which they are rendered liable to future changes.

2. Preliminary knowledge.—These considerations necessarily involve a knowledge of physical laws. We must be acquainted with the chemical constitution of matter, with the combinations its elements are capable of forming, with the liabilities of the com-

pounds to enter into new arrangements, and with the laws which govern these changes. The mechanical laws must also be kept in view; the weight, pressure, and moving power of solids and fluids, the varieties and force of attraction; in a word, the dynamics of our globe. Nor can the subject be considered entirely apart from the planetary relations of the earth, as a member of the solar system, and of the innumerable systems which compose the stellular universe.

Those subtle agents unknown in their essence, but most manifest and potent in their effects—namely, heat, light, electricity, and magnetism, either distinct, or combined in various modifications, demand also a faithful study, that we may comprehend their manifold and unceasing effects in the economy of the earth; nor must the enveloping ocean of aerial fluid, the atmosphere, in which their energy is so largely displayed, be forgotten; both in its physical and chemical characters, it demands earnest attention. We must also know the outlines of natural history, especially of the mineral species, or, at least, of those which are, or have been, chiefly concerned in producing, by their extension or aggregation, the mountains and continents, and the entire crust of our planet, so far as it is cognizable by man. Some competent knowledge of mineralogy ought, therefore, to precede the study of geology; it is true, we may begin with a comparatively small number of the most important minerals, as our increasing acquaintance with rocks will constantly augment our familiarity with the minerals which compose them.

In like manner, as mineralogy is indispensable to the study of geology, so the other departments of natural history are auxiliary to it in a most important degree. Animals and plants, either entire or dismembered, or in fragments, are contained in almost all kinds of rocks, except the primary and the volcanic; nor can we assign the limit of organic matter even in these, for we know not how far fire, by softening or fusion, may have obliterated the organic remains that might once have been blended with materials now exhibiting no vestiges of plants or animals. Although we may not be able to mark the precise boundary beyond which organic beings do not appear, it is certain that in all geological epochs, subsequent, at least, to that of the primary rocks, animals and plants have existed in successive families; they have been created, have lived their destined periods, and by the operation of physical causes have perished, while new races have been called into being, and in their turn have ceased to be, in order to give room to other families, requiring, perhaps, new physical conditions.

Thus we travel onward in time, and upward in the order of deposition, through races whose species are entirely extinct, until we arrive at the periods that approximate to our own times, when first, similar beings to those that now inhabit the earth begin to appear, and finally to graduate into those of the present day. Now it is obvious, that to judge intelligently of extinct races of animals and vegetables, it is requisite to pass in review the entire organic creation, both of ancient and modern date; not only of the terrestrial animals that, in early times, walked the earth, of the fishes and amphibia that swam in the waters, of the birds, insects, and winged reptiles that soared in the air, and of the plants that adorned the new-born islands and emerging continents, and which, as well as the animals, are now entombed in rocks and mountains; but, we must be familiar, also, with the races which, at this moment, fill the world with animation and beauty, for they are our living standards of comparison. In short, we must be well acquainted with both natural history and comparative anatomy.

If such be the circle of sciences preliminary or auxiliary to geology, it may well draw from us the desponding exclamation, Who then is sufficient for these things? We may perhaps reply, no unassisted individual! Science is formed by the joint labours of many minds. Different cultivators bring in the rich tribute of the fields they have tilled and reaped, and a master mind disposes them in order, and draws from them the requisite conclusions to construct a system, or, at least, to furnish its most important elements.

3. Rank among the Sciences.—This very general sketch of the relations which geology sustains to the collateral sciences, is sufficient to evince its high dignity, and to vindicate its strong claims to our serious attention. As a science, its date is modern; but this is also true of all the physical sciences, among which geology is a younger sister. Although it is rapidly advancing, and is, therefore, not perfect, but progressive, it is still a science; and in this sense, which of the physical sciences is perfect?* In this

* "To boast of a stability of opinion in Geology, is to boast of an extreme indolence of mind; it is to remain stationary in the midst of those who go forward."—*Baron Humboldt.*

respect geology is, therefore, not alone. Its ascertained facts are numerous; they are correctly observed and reported; they are skilfully classed, and a sufficient number of general as well as particular conclusions has been drawn from them to furnish the basis of a noble science. Its boundaries are daily extending, and will be extended without limit, by continued observations—its evidence will constantly accumulate, and although its theoretical speculations may change, nothing can occur to subvert the grand conclusion, that the earth has a regular structure, and that its materials have been arranged under the operation of general laws of great energy and duration, the physical expression of omniscient intelligence and omnipotent sway, guided by benevolent design, which becomes more and more apparent and convincing with every new and successful research in geology.

4. Sources of its evidence.—If the inquirer ask for the source of geological evidence, it may be answered that it is derived from diligent and careful examination of the structure of the earth; and for this object our means are more ample than might at first appear.

Every artificial excavation—every well and cellar—every cut for a fort, for a common road, a railway, or a canal—every stone quarry—every tunnel through a mountain—and every pit and gallery of a mine bored into the solid earth, furnish means of perusing its interior structure. Still more do the inland precipices, and the rocky promontories and headlands along the rivers, lakes, seas, and oceans; the naked mountain-sides ribbed with strata, that bound the defiles, gorges, and valleys; the ruins accumulated at the feet of lofty pinnacles and barriers, and those that have been transported and scattered, far and wide, over the earth, present us with striking features of the internal structure of our planet.

Most of all, do the inclined strata push up their hard edges, in varied succession, and thus faithfully disclose the form and substance of the deep interior, as it exists, many miles beneath the observer's feet.

Volcanic eruptions throw up into daylight the foundations of the fathomless deep below, in the form of ejected or molten masses, or in rivers of ignited and fluid rocks, which congeal on the surface of the ground, either inflated like the scoriæ of furnaces, or in solid masses, with no visible impress of heat; and often containing very perfect and beautiful minerals, elaborated in the volcano, or dislodged from still earlier beds. In addition to the products of actual volcanoes—the ignigenous rocks, crystallized or deposited from fusion, both in the earliest and in many of the more modern epochs —injected among, and traversing strata of all descriptions and ages, and thus assimilated to known products of internal fire, the proper rocky masses, the granites, sienites, porphyries, serpentines, and traps, give authentic information of the unapproachable gulf of fire whence they were projected.

The internal waters that gush cool from the fountains on the land or under the sea, or those that spout in boiling geysers from the deep caverns where their imprisoned vapours accumulate explosive force; all these bring to the surface the materials of the interior, and conspire with tornadoes of gas, bursting from volcanoes and other vents, to reveal the deep secrets of the earth.

5. Its positive utiity.—Geology, in addition to its inherent dignity, puts forth strong claims to regard on the ground of positive utility. Every thing reposes upon the mineral kingdom; it affords to man, directly or indirectly, all the materials of his physical comfort—all those of national wealth, and all the means of civilization. The most important of physical instruments are derived, immediately or remotely, from it, for the vegetable world, equally with the animal, rests upon this basis; whether we speak of the cedar, the oak, the lichens, or the grasses, all equally derive their support from the elements afforded by the mineral kingdom; which, in its widest sense, includes not only the solid earth, but its waters, and all its fluids—its atmosphere and all its gases. The vegetable kingdom borrows not a few elements from the mineral world; oxygen, carbon, hydrogen, and even nitrogen, and all that are indispensable to vegetable life, are found in the waters, or in the atmosphere; while other elements or compounds, adapted to particular purposes, are derived from various mineral sources; the soil, for example, affords silica, which enters into the composition of the epidermis of grasses, bamboos, equiseta, &c.; and potass and soda, derived from decomposed felspar and other minerals, pass by absorption into the juices of plants. Even animal and vegetable manures form no exception, for their elements have a similar origin, and consist almost entirely of the substances indispensable to vegetable growth.

Thus, while we explore this orb of gases, fluids, and solid rocks, we shall gain the most interesting knowledge, and much positive advantage. Our beautiful planet is indeed worthy of our study; it was once our cradle—it will soon be our grave,—between the dawn and the night of life, it is the scene of our busy action, and from it we shall rise to another state of being.

6. Discovery of useful Minerals.—Geology discloses to us the valuable minerals, and teaches us where they are likely to be found, and where research would be vain.

Coal.—Coal is, without doubt, wholly of vegetable origin: hundreds of species of plants have been distinguished in the coal formation, but none of these have been found living on the earth, although many of the families still exist; the recent allied species are generally of a diminutive size, in comparison with those of the coal period, and those that approach the ancient in magnitude, are chiefly found in tropical climates.

Duly informed in geology, we should never look for coal in granite,* nor among the most ancient rocks; and in the wide intervening series, a large part of the formations are excluded from the association with this most important mineral. Slates, shales, and limestones, charged with bitumen, afford indications of some value, but not decisive, as bitumen is associated with many minerals that do not belong to coal formations. The impressions of plants in the rocks, especially those charged with bitumen, strengthen the presumption, and should we find fragments of coal scattered in the soil, or mingled with gravel and sand in the banks and water courses, or observe dark masses of earth, which, on close inspection, appear to contain fine coaly matter, we may infer that beds of this combustible may be near, and that it may be proper to dig or bore; and when, at last, we find the beds of coal, they will be regularly arranged between a roof and floor of coal-slate or shale. But it by no means follows, that beds of shale and slate necessarily indicate coal; those of the primary series would scarcely contain any combustible, unless it were plumbago, or possibly a little anthracite. The geological laws of coals are very strict, and a thorough acquaintance with them is the only safeguard against fruitless enterprises.

Lignite.—It is easy to mistake beds of lignite for coal: lignite, when found in sufficient abundance, is a valuable combustible, but it

* Coal strata sometimes repose *upon* granite, (not *in* it,) as in France, and near Richmond, in Virginia.

is not perfect coal; it burns with a sharp and acrid odour like the smoke of a wood fire, and is in fact wood only partially altered by inhumation. It is most abundant in the more recent geological formations, especially in tertiary sands, gravel, and clays, in which true coal has rarely been found. The trees that are buried in the recent alluvial and diluvial deposits are little altered, and are, for the greater part, referable to existing floras; sometimes they are flattened by pressure, and altered in their texture, and even partially carbonized.

Limestone and Marble.—Limestone, including chalk and marble, is a most useful substance. The ancient Grecian temples give decisive proof of the durability of marble; and its beauty, even after the lapse of two or three thousand years, and after innumerable aggressions by the violence of war, and the depredations of antiquaries, more destructive than the action of the elements, is in many instances not entirely destroyed. Limestone is the most important ingredient in mortar, and of great value in soils. But it is not necessary to enlarge on a subject so generally understood. It is sufficient to remark, that in the selection of limestone for architectural purposes, or as a fertilizing ingredient for soils, geological skill will often prove of great value; and in cases of high responsibility, such as those of public edifices, intended to endure to distant ages, the united services of the geologist, the stone-mason, and even the quarry-man, may well be put in requisition, for practical artists often acquire the skill to judge very correctly of the value of materials. The experience of all antiquity proves this to be true.

Various Rocks.—The same view may be taken of granite and sienite, and the slaty rocks of that family, of porphyries, traps, and soapstones, of sandstones and puddingstones, or breccias. All these are employed either in constructing the external walls, or in forming the interior decorations of buildings, as well as in forts, docks, bridges, quays, aqueducts, and roads; and it is of the utmost importance that time and expense should not be bestowed upon materials that are faulty, or worthless; for some kinds of sandstones, limestones, and even granites, crumble away, upon exposure to the air and the weather, and thus produce deformity and dilapidation, where everything should be solid and enduring. In general, this error may be avoided by a careful observation of the effects of time and the weather upon such masses of rocks as chance to be prominent above the ground, and have therefore been (perhaps for ages) subjected to those atmospherical agencies, which the finished edifice must, in its turn, encounter.

Metals.—The researches for metals have ever interested mankind in a high degree, and on no subject are they more liable to error and imposition. Happily, the most important metal, iron, is the most abundant. But iron ores are not always known by the uninstructed; some of the most valuable are not attracted by the magnet, until they have been heated in contact with carbon or hydrogen. Other ores are so completely disguised, that they are not recognised at all by those acquainted with the purified metals alone. This arises from their combination with various substances, chiefly oxygen, sulphur, acids, or arsenic, which, on account of the great change they produce in the properties of metals, are called mineralizers. Iron pyrites, an abundant mineral of little value, is frequently mistaken for gold, because it is usually yellow; and this, notwithstanding it is hard and brittle, while gold is soft and malleable, so that a mere blow of a hammer would detect the difference. Yellow mica has been gathered for gold dust; and silvery mica, and white arsenical iron, have been mistaken for silver.

Calamine, the native oxide of zinc, has no resemblance to any metal whatever; and *tin-stone,* the native oxide of tin, has none to that metal; and both would be rejected by an ignorant observer. The same may be said of the sulphuret of silver, the gray sulphuret of copper, the chromate, molybdate, carbonate, phosphate, and sulphates of lead, and many more. Few persons, indeed, trust themselves to carry on great works in mining, without previously consulting professional men; some are, however, so perverse, or blinded, as to persist even against the best counsels, and they, of course, pay the penalty of their folly in disappointment, and oftentimes in utter ruin.

Geological associations of metals.—It is well known to geologists, that metallic veins are rarely found in the most recent formations; and, with the exception of iron, and of alluvial deposits of other metals, they seldom occur in great abundance, until, in the descending series, we approach or pass the geological epoch of coal. In the transition rocks, certain metals abound, while others occur in the primary, and there is no rock so old that it may not contain some of the metals. Sound scientific views of the geological structure of a country, will therefore serve as an important guide in the research for metals, and in forming a conclusion as to the probable continuance, enlargement, or cessation, of metallic veins.

Decisions of Science.—The negative which science often pronounces with entire confidence, may save many an excited mind from delusion, and preserve for agriculture, and the useful arts of life, the resources which might have been lavished, in reckless profusion, upon vain and unproductive mining operations. It is rarely that metallic mines will justify the abandonment of a useful calling in the common walks of life; even where there is abundance of valuable ore, few individuals can, alone, afford to encounter the enormous expense of mining, and to wait its uncertain, and, it may be, distant and stinted returns. A good quarry of soapstone, granite, gypsum, or sandstone, may be worth more than a mine of gold, and such have actually been the opposite results in some signal cases in this country. To these few instances of the importance of geological knowledge to the common interests of life, many more might be added, but these are sufficient to illustrate our argument; if, indeed, it be necessary to prove, that he who acts with consummate knowledge proceeds with safety, walking in the full and certain light of science, while he who adventures in the dark has no right to expect anything but disaster and ruin.

Geological Surveys by Public Authority.—That there is a just appreciation of this subject among the people of this country, is sufficiently evinced by the geological surveys of many states and territories, either already accomplished or in progress. More than one-half of the States have, by public authority, instituted such surveys; the reports which have been published evince industry, knowledge, and skill: great progress has been made in developing the mineral resources of the country, and in amassing stores of materials to serve for a future digested and systematical account, both scientific and practical, of North American geology; while, at the same time, excellent schools are thus established, in which to form young geologists by actual and responsible explorations and surveys. These good works will, we trust, proceed, until our whole territory has been geologically examined, when some gifted individual will give us the grand result. In a scientific relation, these researches are deeply interesting, and we are in this way, as well as by personal efforts, contributing our share of materials towards the general stock of geological knowledge.

7. Some features in North American Geology.—Perhaps

no country is more favoured than our own, in the nature, abundance, variety, and distribution, of the most important mineral treasures. The limits of these preliminary remarks can only present the most general summary of our geological formations, or at most, admit of nothing more than a mere sketch; but the materials for information are already abundant, and are yearly increasing, as may be seen in the various public reports, in the transactions of our learned societies, and in our journals of science.

Of the primary and transition rocks, to which we may add the coal formation and the silurian, we have immense ranges, extending in a north-easterly and south-westerly direction through the continent, and comprising most of the minerals, and many of the fossils, that are found associated with such groups in the old world.

The Alleghanies, (including many mountains having local names,) following the general bearing of N.E. and S.W., and ranging between the Mississippi and the Atlantic, form, with their branches and connected chains, the great rain-shed of the countries east and west; and rising to two, three, four, and five thousand feet and more,* give direction to the streams and rivers, that flow either into the Mississippi, the Atlantic, or the great lakes, and the St. Lawrence.

Rocky Mountains.—In like manner, the far more stupendous chains of the Rocky Mountains, whose loftiest peaks are reported to be between three and five miles high,† give a geological character to the regions east and west, in which directions the waters flow to the Mississippi and the Pacific, while other contributions descend to the Gulf of Mexico, and to the Northern Ocean. It is to be regretted, that in the United States proper, there are no mountain ridges, or solitary peaks, that pierce the regions of perpetual cold.

Mount Washington.—Mount Washington, of the White Mountain group in New Hampshire, which approaches a mile and a quarter in height, and being in 44° of north latitude, on a continent whose average temperature is many degrees below that of Europe, throws off its snowy mantle only for a short season, in July and August,

* Professor Mitchell, University of Chapel Hill, states that the top of Black Mountain, in North Carolina, is 6476 feet above the level of the ocean. See Am. Journal, vol. xxxv. No. 2.

† See Professor Renwick's Outlines of Geology.

while it is clad in white during the remaining months of the year. Even on the first day of September, (1837,) as adventurers upon this Alpine mountain,* we were, both on its flanks and summit, involved in a wintry tempest of congealed vapour, formed into splendid groups of feathery and branching crystals, unlike to the snows of the lower regions: the driving masses came in fitful gusts, veiling in a white cloud all objects far and near; but breaking, occasionally, to admit a flood of solar light, and render visible this hoary pinnacle, and the deep gorges and valleys of the neighbouring groups of mountains.

The mountains of Essex County, State of New York, between Lake Champlain and the St. Lawrence, approach the White Mountains in altitude, but none are permanently snow-clad.

Mountains of Central Europe.—It is otherwise in Europe, where the grand central group of Mont Blanc, and the various Alpine mountains, rise far into the region of perpetual congelation; and Mont Blanc would pierce that region even at the equator. Thus is provided an eternal storehouse of ice and snow, over whose wintry surface the winds, rendered heavier by contact, glide into the valleys and plains of the countries at their feet, and thus temper even the warm climate of Italy, preventing the extreme vicissitudes which we experience.

But these immense natural magazines have a still more important relation to the irrigation of the vicinal countries. The melting of the snow and ice, by the heat of summer, supplies copious streams to feed the innumerable rivers that flow from these grand fountains, to almost every part of continental Europe, south of the Baltic. Thus the effects of drought are, in a great measure, prevented, while destructive mountain-floods are of rare occurrence.

From the absence of such mountains we have no permanent stores of ice and snow, and, consequently, our rivers are liable to extreme variations of altitude and force. The Ohio, in midsummer, sometimes leaves numerous fleets aground, while occasional risings, from deluging rains, swell the river to an immense flood, that spurns the barrier of the banks, inundates villages and cities, and expanding into an internal sea, rushes with wasting violence over the wide-spread meadows and farms. For this reason, hydraulic engineering is in this country attended with peculiar difficulties, both

* See Am. Jour. Science, vol. xxxiv. p. 74.

on account of a deficiency and an excess of water; the former rendering the works inoperative, and the latter invading or sweeping them away.

The future civilized inhabitants of the countries near the Rocky Mountains (excepting, of course, the immense sandy deserts, which, near the eastern slope, emulate the sterility of Arabia and Zahara) will enjoy advantages in many respects similar to those of Piedmont, Switzerland, Germany, and France; and it is easy to predict, that peculiar structures, and a peculiar state of society, will be modelled upon the sublime physical features of those truly Alpine regions. From this, his native land, we have too much reason to expect, that, despite of the efforts of the benevolent to avert the impending doom, the red man of the forest, not reclaimed to humanity, but abandoned to his fate, will vanish before the knowledge and power, and the still more prevailing seductions, of civilized life,—the exterminated victim of cupidity and cruelty.

Influence of Geological Structure on Society.—It is perfectly apparent to geologists, that the scenery of a country is not more exactly stamped by its geological formations than are the manners and employments of its inhabitants.

New England.—Thus the bleak hills and long winters of New England being unfavourable to the most extensive and profitable agricultural pursuits, while the extensive and deeply indented sea-coasts abounding in harbours, headlands, rivers, and inlets, naturally produce an impulse towards the ocean, conspire with the original adventurous character of the population, to send them roving from the arctic to the antarctic circle, till the wide world is laid under contribution by their enterprise. The numerous streams and waterfalls furnish the cheapest means for moving machinery, and thus manufactories spring up, wherever, in the expressive phraseology of the inhabitants, there is *water-power*, and steam supplies local deficiencies of moving force. Ingenuity, conspiring with a general system of education, is excited, under such culture, to produce numerous inventions; and hosts of young men seek their fortunes successfully abroad, as mechanics, seamen, traders, instructors and politicians, and thus operate powerfully, and, we trust, beneficially, on other communities.

Southern States.—The immense tracts of rich alluvium in the southern states—the mildness of the climate—the coasts less abounding with safe inlets, and often modified by the action of the existing ocean, with a population not originally commercial, give a decided impulse to a vast agriculture, and a few great staples form the chief reliance of the landholders. It is easy to see, that this state of things grows out of the newer secondary, the tertiary, and the alluvial formations, which constitute the ocean-barrier from Staten Island to Florida, and from Florida to Texas, extending inland toward the mountains.

Western States.—In the west, the boundless fertile prairies and other tracts of productive soil conspire with remoteness from the ocean, to indicate agriculture and pasturage as the main employment of the inhabitants; while exhaustless beds of coal, limestone, gypsum, and iron, and rich veins of lead and copper, and numerous and copious salt fountains, furnish means for a manufacturing, as well as an agricultural population. These pursuits occupy the greater number of the people, while many find a profitable employment in navigating those immense inland seas, the great lakes and the vast rivers, which run thousands of miles before they mingle with the ocean. This state of things is the result of the immense extent of the lower secondary and transition formations which cover the western states, sustaining portions of tertiary strata, and alluvial deposits.

While New England produces granite, marble, and other building materials of excellent quality, Pennsylvania, with the western and several of the southern and south-western states, supplies inexhaustible magazines of coal, which prompt and sustain the manufacturing interests of this wide country, and aid its astonishing navigation by steam; already of unexampled extent on its internal waters, and destined at no distant day to compete, on the main ocean, in amicable rivalry, with our parent country.

Geological Treasures.—Our coal formations, in richness and extent, are unrivalled in the whole world; our iron and lead are in the greatest abundance and excellence; Missouri has mountains of pure oxide of iron, that have no compeers, and there is a fair prospect that copper will also be found to abound in the West. We have great deposits of limestone and marble, of gypsum, marl, and salt, and of building stones of almost every kind; our soils are so various in quality, and in geographical position, that almost every agricultural production is obtained in abundance. It is obvious, then, that we have all the physical elements of national and individual prosperity, and that the blame will be our own, if we do not follow them up by proper moral and intellectual culture, which, alone, can render them sources of public and private happiness.

Geological deficiencies—Upper Secondary.—Of the upper secondary, below the chalk, and above the new red sandstone, lying higher than the coal, we have no well ascertained strata: rocks of oolite structure we may have, but it is not ascertained that we have the true oolite of England and continental Europe, nor have we traced the Wealden nor the Lias* with their colossal animal wonders.

Equivalent of Chalk.—Chalk, properly speaking, appears to be absent from the United States, but there is an equivalent to the chalk formation in vast beds of sands and marls, containing many European cretaceous fossils, between the Delaware river and the shores of New Jersey, as well as in various places in the south.†

Absence of Volcanoes.—The principal deficiencies in the geological formations of the United States, are in the absence of active volcanoes, and of most of the members of the upper secondary. However interesting active volcanoes, with their earthquakes and eruptions, may be to speculative geologists, the sober unscientific population of our States may well rest contented without them, satisfied to barter the sublime and terrific for quiet and safety. Although the soils formed from decomposed lava are often fertile, and the vine flourishes luxuriantly on the flanks and at the feet of the volcanic mountains of warm countries, these influences are too local to be of much importance to agriculture.

Within the United States proper, including the states and territories beyond the Mississippi, and east of the Alleghany mountains, there is not, so far as we know, a single active volcano, nor even an unequivocal crater of one that is dormant. It remains yet to be decided, whether in and beyond the Rocky Mountains, quite to the shores of the Pacific Ocean, there are any active volcanoes within our parallels of latitude. Both north and south of our limits, there are, on the islands and shores of the Pacific, numerous volcanoes, and it would be strange, indeed, if there were none within our extensive possessions on the same coast.

Records of volcanic action in the far West.—However this may be, there remains no doubt that fire has done its work, on a great scale,

* It is plain that the Lias, so called, in the West, is not the Lias of England.

† See Dr. Morton's Synopsis of Organic Remains of the Green Sands of the United States, 1 vol. 8vo. with plates.

among the Rocky Mountains, and between them and the Pacific; for all our travellers attest the existence of immense regions covered with scoriæ and other decidedly igneous products, as if there had been actual and vast eruptions, within a period too short for decomposition to have reduced those tumefied and semi-vitrified masses into soil.

Trap and Basalt.—Regular formations of trap, and of basalt with symmetrical columns, are common among and beyond the Rocky Mountains, and the rocks of this igneous family are frequent in many parts of the old United States. They abound in New England, New Jersey, and the Carolinas, and, as usual elsewhere, they protrude their dykes among the rocks. In New England, and especially in New Hampshire, they often divide the primary rocks, cutting even granite mountains from top to bottom; branching out, in many places, with numerous veins either dying away to extinction, or, perchance, returning again to the main current after having cut off a portion of the invaded rock. The White Mountains of New Hampshire abound in such phenomena.

Similar intrusions are found in the mountains of Essex, Lake Champlain, New York, and in many other places, and the primary rocks on the coasts of Massachusetts and Maine, as well as in the interior, are wonderfully cut up by invading veins and dykes of trap, basalt, and porphyry, and even of granite itself. It appears, also, that in the state of New York, limestone and other rocks, including the primary, and not excepting granite, are traversed by intrusive trap.*

Tertiary Formations.—Our tertiary formations are exceedingly extensive, and are rich in fossil remains. They bound a large portion of the sea coasts south of New England, quite to the Mexican gulf, and up the Mississippi and Missouri: these oceanic deposits are also found, extending hundreds of miles into the interior from the coasts, where, as well as near the sea, they furnish, in their calcareous marls, inexhaustible resources for agriculture. Even on the shores of New England, there are marine tertiary deposits, as at Gay Head, in Martha's Vineyard, and elsewhere in that vicinity; while there are, in every part of the United States, innumerable inland deposits of fresh water tertiary.

Boulders.—In boulders and rocks of transport our country

* See Professor Hall, in the Geological Reports for 1838.

abounds; vast regions of older secondary and transition strata are occupied, more or less, by ruins of primary rocks, some of them of vast size, while the primary countries themselves, and the transition too, are marked by their own *disjecta membra.* We are precluded by our limits from discussing the causes of their transportation, whether by floods, ice floes, or other motive powers. It is almost unnecessary to remark, that pebbles, gravel, and sand, are found, as in other countries, transported and distributed, without doubt, by the action of water.

8. Beauty and interest of Geology as a Science.—In relation to the beauty and interest of Geology as a science, we can hardly trust ourselves to write, since, within our prescribed limits, we have no room, and there is little occasion to describe that which our Author has, everywhere, treated with signal ability and eloquence. It may, however, serve to engage the attention of those to whom geology is a *terra incognita*, if we, in this place, remark, that no field of science presents more gratifying, astonishing, and (but for the evidence) incredible results. It teaches us that man has been but a few thousand years a tenant of this world; for nothing which we discover in the structure of the earth, would lead us to infer that he existed at a period more remote than that assigned to him by the Scriptures. Had he been cotemporary with the animals and plants of the early geological periods, we should have found his remains, and his works, entombed along with them.

This argument forcibly impressed the mind of Bishop Berkeley a century ago, and the following beautiful passage is cited from him by Mr. Lyell:*—" To any one who considers that, on digging into the earth, such quantities of shells, and in some places bones and horns of animals, are found sound and entire, after having lain there, in all probability, some thousands of years, it would seem probable that gems, medals, and implements in metal or stone, might have lasted entire, buried under ground forty or fifty thousand years, if the world had been so old. How comes it then to pass that no remains are found, no antiquities of those numerous ages preceding the Scripture accounts of time; that no fragments of buildings, no public monuments, no intaglios, cameos, statues, basso-relievos, medals, inscriptions, utensils, or artificial works of any kind, are ever discovered, which may bear testimony to the existence

* Principles, 5th Ed., vol. iii. p. 255.

of those mighty empires, those successions of monarchs, heroes, and demi-gods, for so many thousand years? Let us look forward for ten or twenty thousand years to come, during which time, we will suppose that plagues, famine, wars, and *earthquakes,* shall have made great havoc in the world, is it not highly probable, that at the end of such a period, pillars, vases, and statues, now in being, of granite, or porphyry, or jasper, (stones of such hardness as we know them to have lasted two thousand years above ground, without any considerable alteration,) would bear record of these and past ages? Or that some of our current coins might then be dug up, or old walls, and the foundations of buildings, show themselves, as well as the shells and stones of *the primeval world,* which are preserved down to our times."* This remarkable passage proves that the great man from whom it fell, saw the geological argument in a true light, and felt its force to such a degree as to convince him of the great antiquity of the earth, which he justly viewed, as in no way inconsistent with the comparatively recent origin of man, or with the historical account of both events contained in the Genesis. It is easy to understand how such a mind would have been convinced, warmed, and excited even to enthusiasm, by the discoveries that have burst upon us during the last fifty years.

9. Organic Remains.—As we descend from the alluvial soil under our feet, through the strata, the lowest of which lies upon the granite, or the early slates, we are seldom without the records of life, in ages long past, and those records are drawn both from the animal and vegetable world.

Early Animals.—Shells of molluscous and testaceous animals are everywhere seen; their forms, their casts, their substance, are apparently preserved in stone, but generally converted, by the substitution of mineral matter, into true fossils. Myriads on myriads of these things are found, not merely in the superficial strata, but in the heart of the mountains, and at profound depths, forming an essential part of the solid framework of the globe.† The animals and plants are not accidental resemblances, but authentic specimens of ancient organisms, enclosed in the strata and mountains, as the materials, in mechanical or chemical suspension in the waters, concreted around them.

* Alciphron, or the Minute Philosopher, vol. ii. pp. 84, 85. 1732.

† See the list of strata formed wholly, or in great part, of organic remains, in our Author's Eighth Lecture; and in his "*Medals of Creation.*"

Fossil Fishes.—If we descend from the strata of newest formation, to those that lie near, or upon the primary rocks, we find not only that crustaceous and molluscous animals, of various kinds, have existed in the early periods, but that fishes have occupied the waters of almost all geological ages since life began, and that among the earliest, even those that are buried beneath the coal, there were races of great size, power, and ferocity; formidable from their teeth and jaws, which had, in some species, a structure like those of reptiles; and they had forked tails with unequal flukes, which enabled them quickly to turn over on their backs before striking their prey. The fossil fishes of particular genera and species, are characteristic of particular geological formations—they extend geographically, far and wide, to distant countries, so that certain species may, if found at all, be expected in similar rocks in Europe, in America, in Asia, and Africa; and they are of every size, from inches, and fractions of an inch, to several feet. They occur either solitary—or in groups—or in fragments—or in immense shoals, like those of Monte Bolca, near Verona, in Italy, where there are several hundred species; still, scarcely a single fish of the strata that precede the most recent tertiary, is identical in species with any now existing in the waters of the globe.

Fossil Vegetables.—Vegetables are found in strata of nearly all geological ages, and the labours of Count Sternberg, of M. Adolphe Brongniart, and of many other able botanists, have proved that a peculiar vegetation, adapted to the temperature, the degree of moisture, and other circumstances of the earth's successive surfaces, attended the different geological epochs.

Splendid and expensive works are now in the hands of geologists, containing exact delineations of the fossil vegetables, as far as they have been ascertained. These fossil plants are of all dimensions, from minute confervæ and lichens, to gigantic trees; their structure, from mere fragments to perfect plants, has been beautifully delineated; roots, trunks, branches and leaves, with the most delicate ramifications of the skeletons of the latter, have been examined; and in some rare cases, the more perishable organic fructification has been made out, and the fruits themselves have been identified.*

* See our Author's work, entitled "*Medals of Creation*," for a lucid summary of the fossil remains of animals and plants, at present known.

Vegetation of the Coal period.—The most exuberant vegetation appears to have been that of the coal period, and its entombed treasures now supply the world with fuel, especially in countries where the forests are exhausted, or where economy of the modern vegetation, or preference for the results of the ancient, decides the choice.

Varieties of the Ancient Fossil Vegetation.—The ancient vegetation appears in many forms, as in that of lignite, of coal, and of siliceous, calcareous, and ferruginous petrifactions, still preserving the peculiar structure; and this has been made still more distinct and satisfactory, by cutting thin slices of the petrified trunks, and grinding them down until they become transparent, when the microscope reveals the internal structure, which characterizes the family. Thus, it has been made to appear, that coniferous trees of forest growth, occur in the coal formation in the south of Scotland, and the north of England; and that zamias and other palm-like trees were coeval with the chalk in the south of England. But no species of the ancient world are identical with any of the modern, and the early vegetation implies, generally, a warm and moist climate, and great fertility of production.

Aquatic Animals.—*Reptiles.*—The abundance of remains of animals, almost exclusively of marine species, attests the great prevalence of the ocean in the earlier geological periods, and it is not until we have passed the coal in the ascending order, that we begin to find reptiles of marine or of amphibious families, and ultimately, still higher up, of terrestrial races. With a similarity of type to the families of the present day, both the genera and species are, however, with but very few exceptions, extinct. Some were carnivorous and swam in the shallow seas, estuaries, lagoons, and bays, and preyed upon fishes, molluscous animals, and each other; some lived on land and were herbivorous; a few genera, the megalosaurus and iguanodon, for example, were colossal in size, and terrible in form, but it is probable that the latter of these terrestrial saurians was harmless and inoffensive, while the tooth of the megalosaurus would indicate a carnivorous animal, like the marine saurians. Bones of many genera and species of the reptile tribes, especially the saurians, have been found, and of some individuals, entire, or nearly perfect skeletons;—among them, several of vast dimensions have been discovered enclosed in the solid rocks, along with their petrified and half-digested food, and with their coprolites.

Marsupials.—If the reptiles formed the transition from the marine animals upward, the marsupials, as they are called, were the link between the ancient reptiles and terrestrial quadrupeds. The marsupials, of which the opossum is an example, receive their young (which, when born, are still immature) into an exterior pouch or abdominal sack, and there nourish them at their paps, until they are fitted to go abroad, and to encounter the vicissitudes of their peculiar modes of life. These are the only animals hitherto found below the chalk which approximate to the proper terrestrial character. Dr. Mantell has, however, found the bones of birds in the Wealden beneath the chalk, and our own countrymen, Professor Hitchcock and Dr. James Deane, have discovered numerous tracks of bipeds, probably of birds, some of them of gigantic dimensions, in the new red sandstone of the Connecticut river.

Fossils of the Chalk and Tertiary.—The chalk then follows, with its immense and varied marine treasures—fuci, corals, echinoderms, mollusks, fish, reptiles, with drifted wood, &c.: and then the lower tertiary, still marine: and next, the middle tertiary, where proper and fully characterized terrestrial animals are first found in abundance. Through the remaining beds of tertiary, both marine and fresh-water, we find molluscous animals, fishes, reptiles, and vegetables, verging towards, and many identical with, those of our own times; and occasionally we discover also terrestrial animals, but mostly different from the modern; until, at last, in the diluvium and alluvium, and the most recent sedimentary and concretionary formations, we discern animals and plants, still more and more like those now living, and finally graduating into perfect identity with existing races.

No Fossil Remains of Man.—Man, and his works, appear only in the last stages, associated with such beings as now exist, both in the animal and vegetable world. The pages of our Author will disclose the great variety and extraordinary forms, and, in many cases, colossal dimensions, unrivalled at the present time, of some of the ancient animals, the megatherium—the sivatherium—the dinotherium—the mastodon—the elephant—the hippopotamus—the rhinoceros—the cavern bear—the tiger, and many others. But in consequence of the most recent discoveries of geology, we are hurried from that which is stupendous and vast, to that which is inconceivably minute. The extremes of creation meet in the mineral kingdom. In the solid rocks are found both the colossal reptiles, and the microscopic infusorial animalcules. Ehrenberg has discovered that polishing slate is made up of the cases or shells of animalcules so minute, that forty-one thousand millions of them are required to fill a cubic inch, and these siliceous shields are the cause of the well-known effect of the tripoli, or rotten stone, in polishing steel, &c. An analogous constitution has been discovered in certain flint, opal, and bog iron; and extensive deposits of marl, &c., in this country, are composed of similar remains, figures of many of which have been given by Professor Bailey, in the American Journal of Science. Even the soft parts of the foraminifera have been detected in the chalk and flint of England by our Author.*

10. General Remarks.—Such is a very general and imperfect sketch of the progressive groups of animals and plants, that have inhabited our world, have become extinct, and are, in countless myriads, entombed in the strata, and in the solid rocks. It is only on the upper surface that we discover loose and scattered boulders and fragments of rocks, and beds of gravel, sand, and detritus, the ruins of more ancient strata; in short, such accumulations of drifted and alluvial materials as we could with reason attribute to catastrophes of rising and rushing water, the deluges of geologists, or the deluge of the Scriptures; the latter, almost alone, being admitted to the contemplations of those who are uninstructed in our science. Now, it is a matter of physical demonstration, that the earth existed for many ages before Man was created; the whole course of geological investigation proves this view to be the only one that is consistent with the facts. To be convinced of its truth, it is only necessary to become thoroughly acquainted with the innumerable records of a progressive creation and destruction which the earth contains, inscribed on medals, more replete with historical truth, and more worthy of confidence, than those that have been formed by man; as much more as nature exceeds in veracity, the erring, or mendacious records of the human race.

11. Consistency of Geology with the Scripture History.—Hardly two centuries have passed since the astronomical doctrines

* See Philosophical Transactions, for 1846.

of Galileo, Kepler, and Newton, were regarded as inconsistent with the Scriptures, and therefore heretical; but although the discrepancy of the literal meaning of the Bible with the real truths of Astronomy, is still as great as ever, no one any longer hesitates to regard astronomy as giving a just view of the stupendous mechanism of the Universe;—all agree in understanding the language of the Scriptures as being adapted to the *appearances* of the heavens, of which alone, mankind in general can form any just conception, and with which alone the Scriptures are concerned. The Bible, being designed as a code of moral instruction, as a revelation of a future life, and of the sanctions that belong to that momentous subject, contains no systems of philosophy. Moral science, essentially contained in the Scriptures, is not, even there, presented in a regular form, as in human systems, but in modes more happily adapted to the actual condition and capabilities of mankind.

In relation to physics, the information contained in the Bible is only incidental. God is declared to be the Creator of the heavens and the earth,—the physical universe,—and throughout the sacred volume there are innumerable allusions to, and illustrations of, his character, as its Creator and Governor: but there is not even the most general outline of any physical science. The creation of the heavens and the earth, of the sun and the moon, are disposed of with extreme brevity, while the allusions to the geological arrangements of this planet are only such as are connected with the first appearance of its organized beings, and the emergence of the land from the original ocean.

Instruction in the sciences was not the object of the Scriptures; the physical creation was left by its Divine Author for the delightful exercise of our faculties, and to afford an inexhaustible source of mental and moral pleasure;—for application to use, to increase the power and the comforts of man—an equally unfailing fund of improvement, and for the additional illustration of the character of God; an exhaustless fountain of knowledge, mingling its streams harmoniously with those of divine revelation.

From the study of the physical creation, Man has, therefore, drawn all the natural sciences, of which Astronomy is the most sublime and splendid, while Geology yields, in this respect, only to astronomy. Neither astronomy nor geology is, however, enunciated in the Scriptures, but both are revealed in the book of Nature, and the astonishing truths which they unfold have been brought to light by human research.

While, as already remarked, the science of astronomy is, in fact, inconsistent with the *apparent* movements in the heavens, and, therefore, with the literal and popular phraseology of the Scriptures, which allude to physical things as they appear to the uninstructed mind, and not as they are in reality,—geology presents not even this discrepancy, but, on the contrary, a substantial agreement in its facts with the Scriptures. The latter describe a physical creation of mineral matter, and a successive creation of plants and animals, ending with man; while geology, by irrefragable demonstrations, which nothing but a study of the earth could afford, proves this history to be true.

The Scriptures describe a universal deluge; and geology shows that every part of the earth is marked by the effect of such visitations, occurring at one time, or at many times;—a repetition of local deluges, or a general one, would produce similar results; and although it may be impossible to distinguish between the accumulated effects of local overflows, and a general diluvial devastation, the surface of the earth is everywhere strewn with diluvial debris. The Scriptures declare that there was a beginning, and geology proves that there was a time when neither plants, nor animals, nor man existed; but both the Scriptures and geology are silent as to the period when the fiat of the Creator first called our earth and the planetary systems into being. It was, doubtless, in very remote antiquity, but the commencement is known only to Him who has neither "beginning of years, nor ending of days."

Thus the consistency of geology with the early Scripture history, is susceptible of a perfect and triumphant defence, but it is not to be found in the refinements of exegesis, nor in the forced solution of a general deluge, which is entirely unsatisfactory, and, indeed, impossible, as a cause of the regular formations of the earth, immensely varied as they are, and exuberant in the relics of many *successive* races of the animals and vegetables of past ages. But this consistency is found in the regular induction from facts, in the just understanding of time, and in its extension back beyond the creation of man, so far as to embrace the innumerable events that have certainly happened in the material world.

To this conclusion the religious mind is fast approaching, and its arrival at the goal of truth is as certain as the progress of time; and the period is near at hand, when the great deductions of Geology, like those of Astronomy, will be viewed by the intelligent and instructed as in perfect harmony with the Scriptures, and as affording new proofs of the wisdom, and goodness, and omnipotence of the ETERNAL BEING, who, "*in the beginning created the heavens and the earth.*"

YALE COLLEGE,
NEWHAVEN, CONNECTICUT.

THE

WONDERS OF GEOLOGY.

LECTURE I.

1. Introductory. 2. Nature of Geology. 3. Harmony between Revelation and Geology. 4. Duration of geological Epochs. 5. Structure of the Earth. 6. Geographical Distribution of Animals and Plants. 7. Temperature of the Earth. 8. Nature of the Crust of the Globe. 9. Classification of Rocks. 10. Geological Mutations. 11. Connexion of Geology with Astronomy. 12. Nebular theory of the Universe. 13. Various states of the Nebulæ. 14. Formation of the Solar System. 15. Gaseous state of the Earth. 16. Geology elucidated by Astronomy. 17. Aerolites. 18. Origin of Aerolites. 19. Existing geological Agents. 20. Aqueous Agency: the effects of Streams and Rivers. 21. Deltas of the Ganges and Mississippi. 22. Formation of Fluviatile Strata. 23. Ripple-marks. 24. Lewes Levels. 25. Remains of Man in modern Deposits. 26. Peat Bogs. 27. Conversion of Peat into Coal. 28. Subterranean Forests. 29. Geological effects of the Ocean. 30. The Bed of the Ocean. 31. Effects of Currents. 32. Icebergs and Glaciers. 33. Incrusting Springs. 34. Incrustations. 35. Lake of the Solfatara. 36. Marble of Tabreez. 37. Stalactites and Caverns. 38. Consolidation of loose Sand. 39. Destruction of Rocks by Carbonic Acid. 40. Carbonic Acid in Caves. 41. Consolidation by Iron. 42. Recent Limestone of the Bermudas. 43. Fossil human Skeletons. 44. Isle of Ascension. 45. Drifted Sand. 46. Formation of recent Sandstone. 47. Siliceous depositions. 48. The Geysers of Iceland. 49. Siliceous Thermal Waters of New Zealand. 50. Artificial Solution of Silex. 51. Hertfordshire Pudding-stone. 52. Effects of high Temperature. 53. Volcanic agency. 54. Subsidence and Elevation of the Temple at Puzzuoli. 55. Historical Evidence. 56. Causes of these changes. 57. Elevation of the Chilian Coast. 58. Raised Sea-beach at Brighton. 59. Elevation of Scandinavia. 60. Mutations in the relative Level of Land and Sea. 61. Retrospect.

1. Introductory.—An eminent philosopher* has justly remarked, that in order to obtain a proper sense of the interest and importance of any science, and of the objects which it embraces, nothing more is necessary than the

* Professor Sedgwick.

intent and persevering study of them; for such is the consummate perfection of all the works of the Creator, that every inquirer will discover a surpassing worth, and grace, and dignity, in that especial department of knowledge to which he may peculiarly devote his attention. Whatever walk of philosophy he may enter, that will appear to him the path which is the most enriched by all that is fitted to captivate the intellect, and to excite the imagination. Yet before we can attain that elevation from which we may look down upon and comprehend the mysteries of the natural world, our way must be steep and toilsome, and we must learn to read the records of creation in a strange language. But when this knowledge is once acquired, it becomes a mighty instrument of thought, by which we are enabled to link together the phenomena of past and present times, and obtain a domination over many parts of the natural world, by comprehending some of the laws by which the Creator has ordained that the actions of material things shall be governed.

In the whole circle of the sciences, there is none that more strikingly illustrates the force and truth of these remarks than Geology; none which offers to its votaries rewards so rich, so wondrous and inexhaustible. In the shapeless pebble that we tread upon, in the rude mass of rock or clay, the uninstructed eye would in vain seek for novelty or beauty; like the adventurer in Eastern fable, the inquirer finds the cavern closed to his entrance, and the rock refusing to give up the treasures entombed within its stony sepulchre, till the talisman is obtained that can dissolve the enchantment, and unfold the marvellous secrets which have so long lain hidden.

2. NATURE OF GEOLOGY.—To the mind that is unacquainted with the nature and results of geological inquiries, and which has been led to believe that the globe we inhabit is in the state in which it was first created, and that with

the exception of the effects of a general deluge, its surface has undergone no material change, many of the facts to be noticed in the course of these lectures may appear almost incredible, and the inferences drawn from their investigation be regarded as the vagaries of the imagination, rather than as the legitimate deductions of sound philosophy. If, therefore, it be absolutely necessary, as it unquestionably is, that in the pursuit of knowledge of any kind, before even experience can be employed with advantage, we must dismiss from our minds all prejudices, from whatsoever source they may arise, this mental purification becomes the more indispensable in a science like Geology, in which we meet at the very threshold with facts so novel and astounding; facts which prove, that though man and other living things be, as it were, but the creation of yesterday, the earth has teemed with numberless forms of animal and vegetable life, myriads of ages ere the existence of the human race.

Geology may be termed the physical history of the earth,—it comprehends the investigation of the mineral structure of our globe, and the characters and causes of the various changes which have taken place in the organic and inorganic kingdoms of nature. It has been emphatically denominated by one of our most distinguished philosophers, the sister science of Astronomy. But, relating as it does to the history of the past, and carrying us back by the careful examination of the relics of former ages, to periods so remote as to startle all our preconceived opinions of the age of our planet, the fate of its early cultivators has resembled that of the immortal Galileo and the astronomers of his times; and for a similar reason, namely, the supposed discrepancy between the discoveries and inferences of this science, and the Mosaic cosmogony.

3. Harmony between revelation and geology.—There was a time when every geologist was compelled to

defend himself against imputations of this kind, and it is deeply to be regretted, that there still exists in the minds of many well-meaning persons a prejudice against the study of Geology, from a mistaken apprehension, lest it should weaken our belief in the revealed word of God; for they assume that the results of geological inquiries, and the Mosaic account of the creation of the world, are utterly at variance with each other. But, convinced as I am that there never can be any collision between the doctrines of the purest piety and those of sound philosophy, and that prejudices have been created and perpetuated by authors, who, falsely styling themselves geologists, have mixed up their own vague and erroneous notions with the history of the earth as given by the inspired writer—attempting, with the presumption of ignorance, to account for that which lies beyond the reach of human investigation, and to explain it by evidence equally misapprehended and misapplied—I would most unequivocally assert, that a just view of the nature and limits of geological science warrants no such reproach. Abandoning all attempts to explain the inexplicable, or to reconcile the irreconcilable, it confines itself to its legitimate purpose of accumulating and investigating facts, of pointing out analogies, and indicating the inferences to which they lead; "this is far different from the presumption which would fain prove the truth of Scripture by physical evidence, or the weakness that would found a system of natural philosophy on the inspired record."

Nothing is more unwarrantable than attempts to identify theories in science with particular interpretations of the sacred text; and the caution of Lord Bacon, uttered a century and a half before geology even had a name, cannot be too often repeated. "Let no man," said he, "upon a weak conceit of sobriety, or an ill-applied moderation, think or maintain that a man can search too far, or be too well studied in the book of God's word, or the book of God's works—divinity or philosophy: but rather let men endeavour an endless progress or proficiency in both; only let them beware that they apply both to charity and not to arrogance—to use and not to ostentation; and again, *that they do not unwisely mingle or confound these learnings together*." Deeply impressed with the necessity of strictly obeying this admonition, I have, in all my written and oral discourses on geology, confined myself to a simple statement of the opinions of certain eminent philosophers and divines on this subject—men, alike distinguished for their piety and learning, and who have cultivated with ardour this department of natural science, and have expressed their conviction of its high importance and beneficial influence upon the mind—in the hope that such evidence would be a sufficient and direct reply to the absurd and unfounded charges brought against geology. On the present occasion, I shall content myself with the following extract from a sermon by the Bishop of London: "*As we are not called upon by Scripture to admit, so neither are we required to deny the supposition, that the matter, without form and void, out of which this globe was framed, may have consisted of the wrecks and relics of more ancient worlds, created and destroyed by the same Almighty Power which called our world into being, and will one day cause it to pass away.*"*

Thus, while the Bible reveals to us the moral history and destiny of our race, and instructs us that mankind and the existing races of beings have inhabited the earth but a few thousand years, the physical monuments of our globe bear witness to the same truth; and as astronomy unfolds to us innumerable worlds not spoken of in the sacred records, geology in like manner proves, not by arguments

* Sermons, by Dr. Charles James Blomfield, Bishop of London. 8vo. 1829.

drawn from analogy, but by incontrovertible physical evidence, that there were former conditions of our planet, separated from each other by vast intervals of time, during which this world was teeming with life, ere the creation of man and the animals which are his cotemporaries.

4. Duration of geological epochs.—At the first step we take in geological investigations, we are struck with the immense periods of time which the phenomena presented to our view must have required for their production, and the incessant changes which appear to have been going on in the natural world. But we must remember that time and change are great only with reference to the faculties of the beings which note them; the insect of a day, contrasting its ephemeral life with that of the flowers on which it rests, would attribute an unchanging permanence to the most evanescent of vegetable forms; while the flowers, the trees, and the forests, would ascribe an endless duration to the soil on which they grow: and thus, uninstructed man, comparing his transient earthly existence with the solid framework of the world he inhabits, deems the hills and mountains around him coeval with the globe itself. But with the enlargement and cultivation of his reasoning powers, man takes a more just, comprehensive, and enlightened view of the wonderful scheme of creation; and while in his ignorance he imagined that the age and duration of this planet were to be measured by his own brief span, and arrogantly deemed himself alone the object of the Almighty's care, and that all things were created solely for his pleasures and necessities, he now becomes conscious of his own insignificance and dependence, and entertains more correct ideas of the omnipotence and goodness of his Creator. And while exercising his high privilege of being the only creature endowed with the capacity of contemplating and understanding the wonders of the natural world, he learns that most important of all

lessons—to doubt the evidence of his senses, until confirmed by cautious and patient observation.

With these introductory remarks I proceed to the consideration of the subjects selected for the present discourse, premising, that from the magnitude and diversity of the objects embraced by geology, it is scarcely possible to offer, in the space assigned to a course of popular lectures, even an epitome of the marvels which modern researches have brought to light. This consideration, therefore, must be my apology for the concise manner in which many interesting facts will be noticed; and I would beg of you to consider that lectures of this kind can only present a general view of the philosophy of geology; that they are calculated to excite, rather than to satisfy, a rational curiosity, and cannot supersede the necessity of study, and of personal investigation.

5. Structure of the earth.—The globe we inhabit is a planetary orb, about twenty-four thousand miles in circumference, and of a spheroidal shape; its figure being such as a fluid body, made to rotate on its axis, would assume. The mean density is five times greater than that of water, the interior being double that of the solid external case. From astronomical observations, the original crust of the earth is supposed to have been a superficial coating of solidified matter, produced by the cooling of the surface of an incandescent fluid globe; and on this shell or crust have been slowly accumulated, during the lapse of innumerable ages, the rocks and strata which form the more immediate objects of geological investigation. The thickness of the solid crust of the earth is computed at from 800 to 1,000 miles, but it is not supposed that this shell is uniform in extent or density; on the contrary, it is probable that it is cavernous, and that liquid masses of mineral matter, in various states of fluidity and incandescence, are distributed throughout the interior of the globe. Some of

these subterraneous lakes of molten rock are probably isolated; others may communicate with each other by channels more or less pervious; and the extensive distribution of such sources of heat is supposed to account for the phenomena of earthquakes and volcanoes, and for the constant increase of temperature beneath the surface of the earth, in proportion to the depth that is reached.*

LIGN. 1.—THE SUPPOSED APPEARANCE OF THE EARTH AS SEEN FROM THE MOON.

(From Sir H. De la Beche's Theoretical Geology.)

The earth's surface is computed at 190 millions of square miles; of which three-fifths are covered by seas, and another large proportion by vast bodies of fresh water, by polar ice and eternal snows; so that, taking into consideration sterile tracts, morasses, &c., scarcely more than one-fifth of the

* See the profound investigations "On the state of the interior of the Earth," by William Hopkins, Esq. *Philos. Trans.* for 1839 and 1842.

surface of the globe is fit for the habitation of man and terrestrial animals.* The area of the Pacific Ocean alone, is estimated to be equal to the entire surface of the dry land. The distribution of the land is exceedingly irregular, the greater portion being situated in the northern hemisphere, as a reference to a terrestrial globe, or a map of the world, will clearly demonstrate.

In a geological point of view, dry land is that portion of the earth's crust which is now above the level of the water, beneath which it may again disappear; and from accurate calculations it is proved, that the whole of the materials composing the present land might be distributed over the bed of the ocean, in such manner that the surface of the globe would present an uninterrupted sheet of water; thus we perceive that every imaginable distribution of land and water may have taken place, at different periods, in the earlier ages of our planet.

6. Geographical distribution of animals and plants.—The investigation of the laws which govern the geographical distribution of animals and vegetables is highly interesting; but as my limits compel me to be brief, I must refer you to Mr. Lyell's "*Principles of Geology*," for a full consideration of the subject. It will be sufficient for our present purpose to state, that although it might have been expected, all other circumstances being equal, that the same animals and plants would be found in places of like climate and temperature, this identity of distribution does not exist. When America was first discovered, the indigenous quadrupeds were all dissimilar to those of the Old World. The elephant, rhinoceros, hippopotamus, giraffe, camel, horse, buffalo, lion, tiger, &c. were not met with on the new continent; while many of the American mammalia, as the llama, jaguar, coati, sloth, &c. were unknown in the old.

* Bakewell's Geology.

New Holland contains, as is well known, a most singular assemblage of mammalia, consisting of more than forty species of marsupial animals; of which the kangaroo is a familiar example. The islands of the Pacific Ocean possess no indigenous quadrupeds, except hogs, dogs, rats, and a few bats.

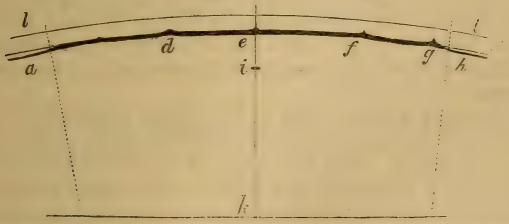
The distribution of vegetable life, though perhaps more arbitrarily fixed by temperature and by local influences than that of animals, presents many anomalies. From numerous observations, however, it is supposed that vegetable creation took place in different centres, each of which was the focus of a peculiar genus or species; for many plants have a local existence, and vegetate naturally in one district alone; thus the cedar of Lebanon is indigenous on that mountain, but does not grow spontaneously in any other part of the world. It is also ascertained that certain great divisions of the vegetable kingdom are distributed over particular regions: we shall have occasion to refer to this subject in the lecture devoted to the consideration of fossil plants.

7. Temperature of the earth.—The temperature of the surface of the globe depends on the action of solar light and heat; hence the difference in the seasons, and climates of various latitudes; but there are many causes which modify the distribution of the sun's influence, and produce great local variations: under equal circumstances, however, the temperature is found progressively to diminish from the equator to the poles. There is also an internal source of heat, the cause of which has not yet been determined, but is supposed to be connected with the original constitution of our planet. It has been ascertained, by careful experiments, that below the point to which the solar influence can penetrate, there is, almost everywhere, an invariable increase of temperature, amounting to 1° of Fahrenheit for every 54 feet of vertical depth: it is therefore possible that

at 100 miles beneath the surface of the earth, even the least fusible rocks and minerals may be in a melted state.

8. Nature of the crust of the globe.—The total thickness of that portion of the rocks and strata accessible to human observation, reckoning from the highest mountain peaks to the greatest natural or artificial depths, is variously estimated at from ten to fifty miles. As the earth is nearly eight thousand miles in diameter, the entire series of strata hitherto explored is, therefore, but very insignificant compared with the magnitude of the globe; bearing about the same relative proportion as the thickness of this paper to an artificial sphere a foot in diameter; the inequalities and crevices in the varnish of such a ball would, in fact, be equal in proportionate size to the highest mountains and deepest valleys.

The depth of the crust of the earth, and the greatest inequalities of its surface, as compared with its mass, are ex-



Lign. 2.—Diagram to illustrate the proportionate thickness of the earth's crust.

pressed in the annexed diagram.* The line from *e* to *k*, represents a depth of 500 miles; to the point *i*, 100 miles; to the line *l*, *l*, forty-five miles above the surface, the supposed

* To preserve as far as possible the language and spirit of the original lectures, the references to the diagrams and specimens are retained.

limit of the earth's atmosphere; and the dark line, *a*, *h*, a thickness of ten miles. The points *d*, *e*, *f*, *g*, indicate the altitude of the highest mountains in the world;* the depth of the sea is shown by the line at the extremities of the arc, *a*, *h*. As a thickness of 100 miles so far exceeds that of the whole of the strata that are accessible to human observation, we cannot doubt that disturbances of the earth's surface, even to ten times the depth of those which come within the scope of geological investigation, may take place, without in any sensible degree affecting the entire mass of the globe.† If these facts be duly considered, the mind will be prepared to receive one of the most striking propositions in modern geology—namely, that the highest mountains were once beneath the sea, and have been raised to their present situations by subterranean agency,—some slowly, others suddenly, but all, geologically speaking, at comparatively recent periods.

* The highest peak of the Alps, and of Europe, is Mont Blanc, which is 15,660 feet above the level of the sea—of the Andes, Chimborazo, which is 21,425 feet—and of the Himalayas, Dhwalagiri, estimated at 28,000 feet, being more than five miles of perpendicular altitude.

† To convey a general idea of the relative magnitude of the inequalities of the earth's surface, Mr. Fairholme suggests the following ingenious method. If we form a scale on the sand of the sea-shore in the proportion of an inch to a mile, we shall have a circle of 8000 inches, or 222 yards in diameter, which when marked out with small stakes, appears a very large area. Placing ourselves upon any part of this circumference, we have an opportunity of taking a just, though microscopic, view of the surface. The highest mountains in the world would be represented by a little ridge five inches high; the profound abyss of the ocean by a groove of the same depth; while the medium inequality of sea and land would not exceed one inch. To form an idea of smaller objects, we must examine an inch scale, finely graduated, by the aid of a microscope, and we shall then find that the tallest man would be about the 880th part of an inch in height—the size of the smallest animalcule observed in fluids, by the aid of the most powerful microscope.

The superficial crust of the globe is composed of numerous layers and masses of earthy substances, of which various combinations of iron, lime, and silex or flint, constitute a very large proportion; the latter forming forty-five per cent. of the whole. Those strata which have been deposited the latest, bear evident marks of mechanical origin, and are the water-worn ruins of older rocks; as we penetrate deeper, deposits of a denser character appear, which also exhibit proofs of having been formed by the action of water; but when we arrive at the lowermost accessible to observation, a crystalline structure generally prevails; and while in the upper stratified rocks, the remains of animals and vegetables are found in profusion, in the ancient crystalline masses all traces of organic forms are absent.

9. Classification of rocks and strata.—In the infancy of the science these remarkable facts gave rise to an ingenious theory, which being founded on insufficient data, has proved untenable. It will, however, be requisite briefly to explain this hypothesis, as some of the terms still employed in geological nomenclature refer to the speculations it suggested. According to this theory the mineral masses composing the earth's crust, are separable into three grand divisions or groups, as follow:—

1st. *Primitive Rocks.*—The Primitive (now termed *Primary*) rocks, are of a crystalline structure, and have evidently been brought to their present state by igneous agency; they comprise granite, sienite, porphyry, &c. These are the lowermost rocks, and constitute the foundation on which all the newer strata have been deposited; they also attain the highest elevations on the surface of the globe. They were termed primitive, because, from the entire absence of organic remains, it was inferred that they were formed before the creation of animals and vegetables; but it is now certain that granite and its associated rocks are of various ages, and it is believed are sedimentary deposits which have been altered by long exposure to a very high temperature.

2d. *Transition Rocks.*—These are super-imposed on the primary, are more or less distinctly stratified, and contain the fossilized remains of animals and plants. They received the name of *transition*, because it was assumed that they had been deposited at a period when the land and sea were passing into a state fit for the reception of organized beings. Modern researches have, however, shown that like the primary rocks, these are strata which have been altered by the effects of heat under great pressure; hence they are now termed *metamorphic*.

3d. *The Secondary Formations.*—These strata have originated, in great part, from the destruction of more ancient rocks, and have been deposited in the basins of lakes, bays, and estuaries, and in the profound depths of the ocean, by the action of rivers and seas. They abound in the mineralized remains of animals and plants; the most ancient enclosing zoophytes and shells; the next in antiquity containing, in addition, vegetable remains and fishes; those which succeed enveloping not only fishes, shells, zoophytes, plants, and insects, but also bones of numerous species of extinct marine and terrestrial reptiles, and of birds, and of a few genera of mammalia. The Chalk is the uppermost, or most recent of this class. As the secondary rocks have manifestly been formed by the agency of water, it is clear that they were originally deposited in horizontal, or nearly horizontal layers or strata, although by far the greater portion has since been broken up, and thrown in directions more or less inclined to the horizon.

For the convenience of study, this subdivision of the rocks is still retained, as will hereafter be shown. To the above groups modern geologists have added two others, namely, the *Tertiary*, and the *Alluvial Deposits*.

4th. *The Tertiary Strata.*—These strata lie upon, and fill up, depressions or basins of the chalk, and other secondary rocks; they consist of the detritus of more ancient beds, and of the relics of shells, plants, zoophytes, crustacea, fishes, &c.: and in them, with but one exception, the bones of mammalia first appear.

5th. *Alluvial Deposits.**—Of a later formation than the tertiary, are those irregular accumulations of alluvial or water-worn and drifted materials, which are spread over the surface of almost every country. In the newest of these beds are found remains of existing races of animals and plants, which, in the most ancient, are associated with those of extinct genera and species.

Even this slight examination of the strata affords convincing proofs of a former condition of animated nature, widely different from the present. We have evidence of a succession of periods of unknown duration, in which both the land and the sea teemed with forms of existence that have successively disappeared and given place to others; and these again to new races, more nearly related to those which now inhabit the earth, till at length traces of existing species appear.

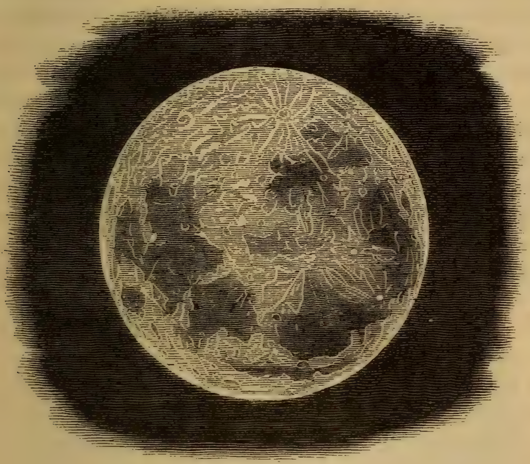
10. GEOLOGICAL MUTATIONS.—From this view of the mineral structure of our planet we learn, at least so far as the limited powers of man can penetrate into the history of the past, that the distribution of land and water on the earth's surface has been undergoing perpetual mutation; yet, that through a vast period of time, its physical condition has not materially differed from the present. We find that the dry land has been clothed with vegetation, and tenanted by appropriate inhabitants; and that the seas and the

* The term *diluvial* is commonly employed to denote the most ancient of these deposits, and that of *alluvial* the more recent, in which existing species of animals only occur.

rivers and lakes of fresh water have swarmed with living things; that at remote epochs, though animals and vegetables existed, the species were distinct from those that now abound, and the greater number fitted to live in a different climate than that which now prevails in the regions where these relics are entombed; and lastly, that in the lowest and most ancient beds, all traces of mechanical action, and of animal and vegetable organization, are absent; in other words, have either never existed, or *have been altogether obliterated.*

11. Connexion of geology with astronomy.—Before entering upon that department of the subject to which the term Geology is commonly restricted, it will facilitate our comprehension of many of the phenomena that will come under our notice, if in this place we endeavour to penetrate the mystery that veils the earliest condition of the earth; but this we shall in vain attempt, if we restrict our observations to the physical phenomena observable in our own planet. Here Geology leads to Astronomy, and teaches us to contemplate the kindred spheres around us for the elucidation of the early history of the globe, and to regard the earth but as an attendant satellite on a vast central luminary. The solar system consists of the sun, which is a mass of solid matter surrounded by a luminous atmosphere, or nebulosity; of twelve planets, which revolve around it in various periods; of eighteen satellites; and of numerous comets, three of which do not pass beyond the orbits of the principal planets. The earth is the third in distance from the sun, and in bulk, as compared with that body, of the size of a pea to that of a globe two feet in diameter; and it has a satellite, the moon, which revolves round it.

Upon examining the moon with a powerful telescope, we perceive that its surface is diversified by hills and valleys, and presents a congeries of mountains, many of which are manifestly volcanic, lava currents being distinctly visible. We see in fact a torn, rugged, sterile area, studded with



Lign. 3.—Telescopic view of the moon.

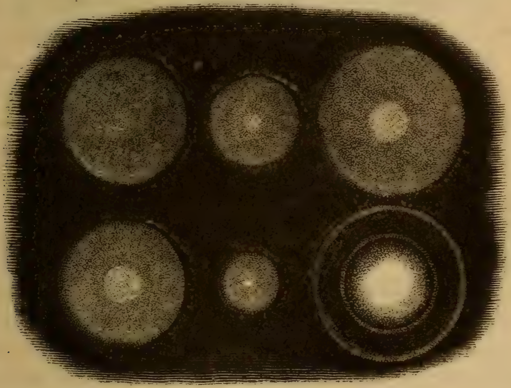
craters, and scarred by rents and chasms, and having such an aspect as we may conceive would be presented by our earth, were the pinnacles of the granite mountains unabraded, and the valleys bare, and not covered and partially filled up by sedimentary deposits.* But there is no evidence of the presence of either air or water in the moon.

12. Nebular theory of the universe. — In the original condition of the solar system, it is supposed that the sun was the nucleus of a nebulosity, or luminous mass, which revolved on its axis, and extended far beyond the

* See Appendix A.

orbit of the most distant of the planets ; these bodies having then no existence. Its temperature gradually diminished, and contracting by refrigeration, the rotation increased in rapidity, and zones of nebulosity were successively thrown off, in consequence of the centrifugal force overpowering the central attraction: the condensation of these separated masses constituted the planets and satellites. This view of the conversion of gaseous matter into planetary bodies is not limited to our own system ; it extends to the formation of the innumerable suns and worlds which are distributed throughout the Universe ; for the discoveries of modern astronomers have shown, that every part of the realms of space abounds in large expansions of attenuated matter, (termed *nebulæ*,) which are irregularly reflective of light, and of various figures, and in different states of condensation, from that of a diffused luminous mass, to suns and planets like the earth.

It must be admitted that this hypothesis is astounding,—and we may well demand if man, the ephemeron of the material world, can indeed measure the vast epochs which mark the progressive development of suns and systems ? The master minds of Laplace and Herschel have effected this wonderful achievement, and explained the successive changes by which it seems probable that suns and planetary systems are formed, through the agency of the sublime laws of the Eternal. By laborious and unremitting observations, those illustrious philosophers have demonstrated the progress of nebular condensation, not indeed from the appearances presented by a single nebula, (for the process, probably, can only become sensible through the lapse of ages,) but by observations on the almost endless series of related contemporaneous objects that appear in every varied state of progression, from that of a cloud of luminous vapour, to the most dense and mighty orbs that appear in the firmament. As the naturalist in the midst of a forest, though unable by a glance to discover that the trees around him are in a state of progressive change, yet perceiving that there are plants in different stages of growth, from the acorn just bursting from the soil to the lofty oak that stands the monarch of the woods, infers, from the succession of changes thus at once presented to his view, the progression of vegetable life, though extending over a period far beyond his own brief existence:—in like manner, the astronomer, by surveying the varied conditions of the heavenly bodies around him, can, by careful induction, determine the nature of those changes, which, as



LIGN. 4.—TELESCOPIC APPEARANCE OF VARIOUS NEBULÆ.

regards a single nebula, the human mind would otherwise be unable to ascertain. And thus have been traced from nebular masses of absolute vagueness, to others which present form and structure, the effects of the mysterious law which appears to govern the stupendous celestial phenomena that are constantly taking place.*

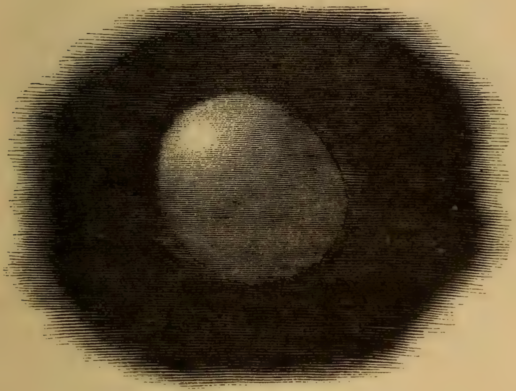
13. Various states of the nebulæ.—Some of the nebulæ appear as mere clouds of attenuated light—others as if curdling into separate masses—while many seem assuming a spheroidal figure. Others again present a dense central nucleus surrounded by a luminous halo; and a series may thus be traced, from clusters of round bodies with one or more increased points of condensation, or of central illumination, to separate nebulæ with single nuclei, and with rings, to a central disk constituting a nebular star; and finally to an orb of light with a halo like the sun!

In the comets, those nebular bodies which belong to our own and other systems, we have evidence that even in the most diffused state of the luminous matter, the masses which it forms are subservient to the laws of orbicular motion: of this fact an interesting proof is afforded by Encke's comet (*Lign.* 5), that mere wisp of vapour, which in a period but little exceeding three years, revolves around the central luminary of our system.

This beautiful theory of Laplace, and of Herschel, explains by an easy and evident process the formation of planets and satellites, and accounts for the uniform direction of their revolutions; and not only is it inferred that such is the law which the Creator has established for the maintenance and government of the Universe, but also that upon mechanical principles, such nebulæ must of necessity consolidate into planetary bodies.

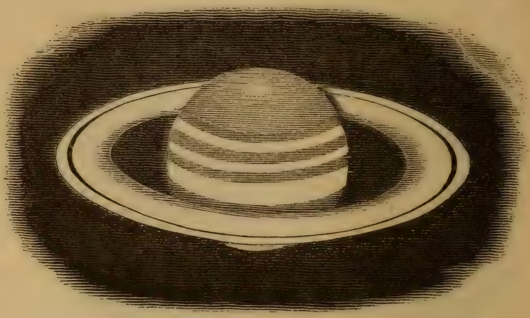
* Although by the enormous powers of the telescope constructed by the Earl of Rosse, it has been ascertained that several of Herschel's nebulæ are clusters of stars, and it is therefore probable that other supposed nebular masses may be brought into the same category, the theory explained in the text will only be modified, not disproved thereby.

14. Formation of the solar system.—In accordance with this hypothesis our sun is regarded as a planetary orb



Lign. 5.—Telescopic view of Encke's comet.

with a luminous atmosphere, the central nucleus of a nebulosity which originally extended to the extreme verge of our planetary system. During the condensation of this nebula the planets were successively thrown off; the most distant, Neptune, being the first or most ancient, followed by Uranus, Saturn, Jupiter, the five asteroids, Mars, the Earth, Venus, and Mercury; the satellites, as distinct worlds, being the most recent of the whole. It is inferred, that in any given state of the rotating solar mass, the outer portion or ring might have its centrifugal force exactly balanced by gravity; but increased rotation would throw off that ring, which might sometimes retain its figure, of which we have a striking example in Saturn, and also in the newly-discovered planet Neptune. This result, however, could not take place unless the annular band were of uniform composition, which would rarely be the case;



LIGN. 6.—TELESCOPIC VIEW OF SATURN.

hence the ring would most generally divide into several portions, which might sometimes be of nearly equal bulk, as in the *Asteroids*, while in others they might coalesce into a single mass. The solar nebulæ, thus separated at various periods, and constituting planets in a gaseous state, would necessarily have a rotatory motion, and revolve in varying orbits around the central nucleus; and as refrigeration and consolidation proceeded, each body might project entire annuli or rings, and satellites, in like manner as the sun had thrown off the planets themselves.

In addition to the appearance of various states of attenuation and of solidity presented by the nebulæ, the orbs of our own system afford evidence of corresponding gradations of density. The planets near to the sun are denser than those which are more distant: thus Mercury, which is the nearest, is the heaviest, being almost thrice as dense as the earth; while the density of Jupiter, which is far removed, is only one-third that of our planet; and Saturn, which, with the exception of Uranus and Neptune, is the remotest, is but little more than one-eighth as dense, and is supposed to be as light as cork.*

You will at once perceive that this theory can in no wise affect the sublime truth that the Universe is the work of an all-wise and omnipotent Creator; "For let it be assumed that the point to which this hypothesis leads us, is the ultimate boundary of physical science—that the nearest glimpse we can attain of the material universe, displays it to us as occupied by a boundless abyss of attenuated matter; still we are left to inquire how space became thus occupied—whence originated matter thus luminous? And if we are able to establish by physical proofs, that the first fact which the human mind can trace in the history of the heavens is, that '*there was light*,' we are irresistibly led to the conclusion, that ere this could take place, 'GOD SAID, *Let there be light*.'"†

This theory of the condensation of nebular matter into suns and worlds, marvellous as it may appear, will be found on due reflection to suggest the only rational explanation of the phenomena observable in the sidereal heavens, and in our own globe, according to the present state of the physical sciences; while its beautiful simplicity is in correspondence with the unity of design so manifest throughout the works of the Eternal.‡

* Introduction to Astronomy, by Sir J. F. W. Herschel. Those who feel desirous of more ample information on this subject, should consult "*Views of the Architecture of the Heavens*," by Dr. Nichol, Professor of Practical Astronomy in the University of Glasgow.

† Professor Whewell.

‡ Dr. Pye Smith, in his able commentaries on the "Relation between Scripture and Geological Science," has the following remarks upon this subject. "The nebular hypothesis, ridiculed as it has been by persons whose ignorance cannot excuse their presumption, is regarded by some of the finest and most Christian minds as in the highest degree pro-

15. Gaseous state of the earth.—Though it may be difficult to the unscientific inquirer to comprehend that our planet once existed in a gaseous state, this difficulty will vanish upon considering the nature of the changes to which all the materials composing the earth are constantly subjected. Water offers a familiar example of a substance existing on the surface of the globe, in the separate states of rock, fluid, and vapour; for water consolidated into ice is as much a rock as granite or the adamant, and, as we shall hereafter have occasion to remark, has the power of preserving for an indefinite period the remains of any animals and vegetables imbedded therein. Yet simply upon an increase of temperature, the glaciers of the Alps, and the icy pinnacles of the Arctic circles, disappear; and by a degree of heat still higher, would be resolved into vapour; and by other agencies might be separated into two invisible gases—

bable. If I may venture to utter my own impression, I must profess it as the most reasonable supposition, and the correlate of the nebular theory, that God originally gave being to the primordial elements of things, the very small number of simple bodies, endowing each with its own wonderful properties. Then, that the actions of those properties, in the ways which his wisdom ordained and which we call laws, produced, and is still producing all the forms and changes of organic and inorganic nature; and that the series is destined to proceed, in combinations and multiplications ever new, without limit of space or end of duration, to the eternal display of His glory."

These remarks may be regarded as a philosophical enunciation of the hypothesis that has been termed "*organic creation by law*," or the formation of living beings from inorganic elements. But this theory is not, at present, substantiated, nor even sanctioned, by any unequivocal evidence: and this absence of all proof appears to me the serious and only legitimate objection to the reception of a doctrine which would explain many obscure physiological phenomena, and bring the laws of vitality into harmony with those which preside over the inorganic kingdom of nature. See the Appendix to my "*Thoughts on Animalcules;*" and Westminster Review, No. XC., article "*Revelations of the Microscope.*"

oxygen and hydrogen. Metals may in like manner be converted into gases; and in the laboratory of the chemist, all kinds of matter easily pass through every grade of transmutation, from the most dense and compact to an aeriform state. We cannot, therefore, refuse our assent to the conclusion, that merely by the dissolution of the existing combinations of matter, the entire mass of our globe might pass into a gaseous or nebular condition.

16. Geology elucidated by astronomy.—From the light thus shed by modern Astronomy upon many of the dark and mysterious pages of the earth's physical history, it appears probable that the dynamical changes which have taken place in our globe—all the transmutations of its crust revealed by geological investigations—may be referable to the operation of the one, simple, and universal law, by which the condensation of nebular masses into worlds, through periods of time so immense as to be beyond the power of human comprehension, is governed.

The internal heat of the globe—the evidence afforded by the crystalline condition of the lowermost rocks of a prevailing higher temperature in an earlier state of the earth—and the elevations and dislocations of its crust which have taken place, and are still going on—all refer to such an origin, and to such a constitution of our planet, as that contemplated by the nebular theory. Nor is the elevatory process peculiar to the earth, for Venus, Mercury, and the moon, exhibit evidence of a similar action; and in the two former the mountains are of an enormous altitude.* In a philosophical point of view, the present physical epoch of our globe "is that of the fluidity of water, which is the nebulous bed or stratum last condensed, and which exerts

* This subject is ably treated in Sir H. de la Beche's "Researches in Theoretical Geology."

mechanical and chemical action upon the previously consolidated materials."*

17. Aerolites.—Intimately connected with this division of the subject, is the remarkable fact of the fall of foreign bodies, called aerolites, or meteoric stones, from the atmosphere. The specimen before us, for which I am indebted to Professor Silliman, is a fragment of a mass which fell at Nanjenoy, in Maryland, North America, a few years since. The following description of its descent, by an eye-witness, will serve to illustrate the ordinary phenomena which attend the appearance of these mysterious visitors.†

"On the 10th of February, between the hours of twelve and one o'clock, I heard an explosion, as I supposed of a cannon, but somewhat sharper. I immediately advanced with a quick step about twenty paces, when my attention was arrested by a buzzing noise, as if something was rushing over my head, and in a few seconds I heard something fall. The time which elapsed from my first hearing the report to the falling, might have been fifteen seconds. I then went with some of my servants to ascertain where it had fallen, but did not at first succeed; however, in a short time the place was found by my cook, who dug down to the stone, which was discovered about two feet below the surface. It was sensibly warm, and had a sulphurous smell: was of an oblong shape, and weighed sixteen pounds and seven ounces; it had a hard vitreous surface. I have conversed with many persons, living over an extent of perhaps fifty miles square: some heard the explosion, while others noticed only the subsequent whizzing noise in the air; all agree in stating that the sound appeared directly over their heads. The day was perfectly fine and clear. There was but one report heard, and but one stone fell, to my know-

* Dr. Nichol.

† American Journal of Science.

ledge; there was no peculiar smell in the air: it fell within 250 yards of my house."*

18. Origin of aerolites.—Mrs. Somerville has the following interesting remarks on this subject:—"So numerous are the objects which meet our view in the heavens, that we cannot imagine a part of space where some light would not strike the eye: innumerable stars—thousands of double and multiple systems—clusters in one blaze with their ten thousands of stars—and the nebulæ amazing us by the strangeness of their forms; till at last, from the imperfection of our senses, even these thin and airy phantoms vanish in the distance. If such remote bodies shone by reflected light, we should be unconscious of their existence; each star must then be a sun, and may be presumed to have its system of planets, satellites, and comets, like our own; and for aught we know, myriads of bodies may be wandering in space, unseen by us, of whose nature we can form no idea, and still less of the part they perform in the economy of the universe. Nor is this an unwarranted presumption: many such do come within the sphere of the earth's attraction, are ignited by the velocity with which they pass through the atmosphere, and are precipitated with great violence to the earth. The fall of meteoric stones is much more frequent than is generally believed: hardly a year passes without some instances occurring; and if it be considered that only a small part of the earth is inhabited, it may be presumed that numbers fall into the ocean, or on the parts of the land uninhabited by civilized man.——The obliquity and velocity of the descent of meteorites, the peculiar substances of which they are composed, and the explosion attending their fall, show that they are

* An analysis of this meteorite gave the following results:—*Oxide of Iron*, 24; *Oxide of Nickel*, 1.25; *Silica with earthy matter*, 3.46; *Sulphur, a trace*; = 28.71.

foreign to our planet. Luminous spots, altogether independent of the phases, have been seen on the dark parts of the moon; these appear to be the light arising from the eruption of volcanoes; whence it has been supposed that meteorites have been projected from the moon by the impetus of volcanic eruption. For if a stone were projected from our satellite in a vertical line, with an initial velocity of 10,992 feet in a second—a velocity but four times that of a ball when first discharged from a cannon—instead of falling back to the moon by the influence of gravity, it would come within the sphere of the earth's attraction, and revolve around it. These bodies, impelled either by the direction of the primitive impulse, or by the disturbing action of the sun, might ultimately penetrate the earth's atmosphere and arrive at its surface. But from whatever source meteoric stones may come, it is highly probable that they have a common origin, from the uniformity, we may almost say identity, of their composition."*

These masses present a general correspondence in their chemical composition and appearance, having (with the exception of native iron) a crystalline character internally, and externally a black slaggy crust, as in this specimen from Nanjenoy.

Obers states that aerolites have been found in tertiary and secondary strata; if so, we must conclude that before the last arrangement of the earth's surface, meteoric stones had fallen upon it.

Baron Humboldt observes that aerolites afford the only direct experimental knowledge we possess of any of the specific properties or qualities of matter not belonging to our globe. "Their direction and enormous velocity of projection (a velocity wholly planetary) render it more than probable, that these masses, enveloped in vapours and

* Connexion of the Physical Sciences, p. 423, 4th edition.

reaching the earth in a high state of temperature, are small heavenly bodies which the attraction of our planet has caused to deviate from their previous path. The aspect so familiar to us of these aerolites, and the analogy which their composition presents to minerals contained in the crust of the earth, is very striking. The inference to which they point appears to me to be, that the planetary and other masses were agglomerated in rings of vapour, and afterwards in spheroids, under the influence of a central body; and that being originally integral parts of the same system, they consist of substances chemically identical."*

19. EXISTING GEOLOGICAL AGENTS.—Assuming then that our planet, when first called into being by the fiat of the Creator, was a gaseous mass, "without form and void," and destined through indefinite ages to undergo mutations which ultimately rendered it a fit abode for man and the animals which are his contemporaries, we proceed to investigate the nature and effects of the agencies by which its surface is still modified.

In this division of the subject it will be my object to explain in a clear and familiar manner some of those physical changes which, unheeded or unappreciated, are taking place around us; but which, operating on a large scale, and through a long period of time, are capable of producing effects that materially modify the earth's surface, and give rise to results which, when viewed in the aggregate, fill the uninformed mind with astonishment, and lead it to call up imaginary convulsions and catastrophes to explain the result of some of the most ordinary operations of nature. As the simple lines that compose the alphabet constitute, when placed in combination, the mighty engine by which the master spirits of our race enlighten and

* *Cosmos;* a Sketch of a Physical Description of the Universe, by Baron Humboldt; Col. Sabine's translation.

benefit mankind, so natural processes, in themselves apparently inadequate to produce any important effects, become, by their combined and continued operation, an irresistible power, by which the dry land is converted into the bed of the ocean, and the bed of the ocean into dry land ; thus fulfilling the universal law of nature, which subjects every particle of matter to incessant change.

Before proceeding farther in this inquiry, I would notice an opinion, so generally prevalent that it may possibly be entertained by some of my readers, namely, that the phenomena which will come under our consideration, have been occasioned by the deluge recorded in Scripture. But whatever may have been the modifications of the earth's surface produced by that catastrophe, they must on the present occasion be wholly excluded from our consideration, for the changes to which geological inquiries relate are of a totally different character, and referable to periods long antecedent to that miraculous event.

I have now to direct your attention to certain natural operations which, when properly investigated, will afford an easy explanation of facts of the highest interest and importance, which present themselves at the first step we take in our inquiry ; will teach us how this limestone has been formed of brittle shells, and this marble filled with the coral to which it owes its beautiful markings—how wood has been changed into stone, and plants and fishes have become inclosed in the solid rock. I have to explain to you that the ground on which we stand was not always dry land, but once constituted the bed of the sea—that the hills, now so smooth and rounded, and clothed with verdure, have been formed in the profound depths of the ocean, and may be regarded as vast tumuli, in which the remains of beings that lived and died in the early ages of the globe are entombed ;—and that the wealds of Kent and Sussex, those rich and cultivated districts which fill up the area between the chalk hills of Sussex, Surrey, Kent, and Hampshire, were once the delta of a river, that flowed through a country which is now swept from the face of the earth—a country more marvellous than any that even romance or poetry has ventured to portray.

20. AQUEOUS AGENCY: THE EFFECTS OF STREAMS AND RIVERS.—The operations we have now to consider are produced by a substance, the most abundant in nature, and with the properties of which we are so familiar, that we but little appreciate the marvellous phenomena they present. This substance—which in one state constitutes vast islands and continents, forming masses that rival in transparency and brightness the rock crystal or the diamond, and are more durable than granite, and so sterile as to afford no sustenance, even to the simplest forms of vitality—in another condition is invisible, and separates into two gases, which supply heat and light to organic bodies;—in a third state it exists as an elastic vapour, which yields to man a power far surpassing that of the fabled wand of the magician, enabling him to cross the ocean in spite of the elements, and traverse the land with a rapidity exceeding that of any other animal;—and lastly, it appears as a fluid which is the essential support of animal and vegetable life, and covers a large portion of the surface of our globe; affording in its profound abysses a habitation for the most colossal of existing animals, and containing in each drop myriads of the minutest beings which the aided eye of man is able to descry!—such are the wonderful properties of the substance that, in its fluid state, we term *water*, and the geological effects of which we now proceed to examine.

In pursuance of this object, we will first notice the changes produced on the surface of the land by the agency of streams and rivers. I need not dwell on those meteorological causes by which the descent of moisture on the surface of the earth is regulated; but will merely observe, that rivers are the great natural outlets by which the superfluous moisture of the land is conveyed into the grand reservoir, the ocean. And so exactly is the balance of expenditure and supply maintained, that all the rivers on the face of the earth, though constantly pouring their mighty floods into the ocean, do not affect its level in the slightest perceptible degree; we may therefore assume that the quantity of moisture evaporated from the surface of the sea and descending on the earth in rain and vapour, is exactly equal to the sum of all the water, in all the lakes and rivers in the world.* But though the quantity of fluid poured by the rivers into the basin of the ocean is again removed by evaporation, yet there is an operation silently and constantly going on, which becomes an agent of perpetual change. The rivulets which issue from the mountains are more or less charged with earthy particles, worn from the rocks and strata over which they flow; the united streams in their progress towards the rivers become more and more

* The quantity of water that percolates into the earth from the surface is very great. It is well known that the water in mines varies with, and depends upon, the rain falling in the districts where they are situated. Seasons of heavy rain are followed by a great increase of water in a mine, and the reverse happens from a drought. The time which elapses before the effect of these causes manifests itself varies considerably, and depends on the mineralogical character and physical features of the country. In carboniferous limestone districts the percolation of rain-water is particularly rapid, so that a heavy fall of rain will often overpower the machinery sufficient for ordinary drainage. "In two mines in Flintshire, the steam-engines, after having been increased in speed from three or four strokes per minute to the extent of their power, about five times as many, were yet incapable of preventing the water from rapidly increasing and filling the workings. In these mines there are great cross courses or faults, which can be traced several miles, and pour torrents of water into the veins; they are, in fact, channels for subterranean rivers, and the latter carry with them large quantities of sand and gravel, worn away from the rocks through which they pass."—*Mr. Taylor.*

loaded with adventitious matter; and as the power of abrasion becomes greater, by the increase in the quantity and density of the mass of water, a large proportion of the materials is suspended in the fluid, and carried into the sea. If the current is feeble, much of the mud, and the larger pebbles, will be thrown down in the bed of the river—hence the formation of alluvial plains, as for example those in the valleys of the Arun, the Adur, the Ouse, and Cuckmere, in this county.* But a great quantity is transported to the mouths of the rivers, and there forms those accumulations of the fluviatile spoils of the land which constitute deltas; the finest particles, however, are carried far into the sea, and, transported by currents and agitated by the waves, are at length precipitated into the profound and tranquil depths of the ocean. But rivers convey not only the mud and other detritus of the countries through which they flow; leaves, branches of trees, and other vegetable matter, and the remains of the animals that fall into the streams, with shells and other exuviæ, human remains, and works of art, are also constantly transported and imbedded in the silt and sand of the deltas and estuaries, and some of these remains are occasionally drifted out to sea, and deposited in its bed.

21. Deltas of the Ganges and Mississippi.—The changes here contemplated, as they are going on in our own island, may appear insignificant, and incapable of producing any material effect on the earth's surface; but if we trace the results in countries where the agents under review are operating on a larger scale, we shall at once perceive their importance, and that time only is required for the accumulation of strata, equal in extent and alike in character with many of those ancient deposits, which will hereafter come under our observation.

* Sussex.

From experiments made with great care, it has been ascertained that the quantity of solid matter brought down by the Ganges and carried into the sea annually, is 6,368,077,440 tons: in other words, a mass of solid materials, surpassing in size and weight sixty times that of the great pyramid of Egypt; the base of that stupendous structure covering eleven acres, and its perpendicular height being 500 feet.* The Burrampooter, another river in India, conveys annually as much earthy matter into the sea as the Ganges. The waters of the Indus, as the late Sir Alexander Burns informed me, are alike loaded with earthy materials. In the vast rivers of America, the same effects are observable; the Mississippi, which flows through twenty degrees of latitude and seven of longitude, and drains a valley 3,000 miles long and nearly 1,000 broad, brings down whole forests and immense rafts, composed of trunks and branches of trees, and drifted underwood, and transports them to its delta, which extends several hundred miles out to sea; and the basin around the embouchure of that river is becoming shallower every day, by the sole agency of the causes now under consideration. The delta of this mighty stream is computed by Mr. Lyell to be at least between 500 and 600 feet in depth, the area it covers nearly 14,000 square statute miles, and the solid matter annually added 2 billions 700 millions of cubic feet; and the period required for the formation of the deposits now composing the delta, at more than 60,000 years.†

In the sediments of these rivers, remains of the animals and plants of the respective countries are continually enveloped. It is therefore evident, that should the deltas become dry land, the naturalist could, by an examination of the animal and vegetable remains imbedded in the

* Lyell's Principles of Geology.

† Lecture on the Delta of the Mississippi, before the British Association, at Southampton, 1846.

fluviatile sediments, readily determine the characters of the fauna and flora of the countries through which the rivers had flowed. We may here observe, that in tropical regions, where animal life is profusely developed, and but little under the control of man, the animal remains buried in the deltas are far more abundant than in those of European countries, which are thickly peopled, and in a high state of civilization. The enterprising but unfortunate Lander informed me, just before he embarked on his last and fatal expedition to Africa, that many parts of the Quorra, or Niger, so far as the eye could reach, teemed with crocodiles and hippopotami; and so great was their number, that he was often obliged to drag his boat on shore lest it should be swamped by them.

It is unnecessary to dwell longer on these operations; it will suffice to have shown, that by the simple effect of running water, great destruction and extensive modifications of the surface of the land are everywhere taking place, and at the same time fluviatile deposits are forming on an extensive scale, and imbedding animal and vegetable remains. Thus, in the deltas of the rivers of England are found the bones and antlers of the deer, horse, and other domesticated animals, associated with the trunks and branches of trees and plants, river and land shells, human bones, and fragments of pottery and other works of art: while in those of the Ganges and the Nile, the remains of the animals and vegetables of India and of Egypt are respectively entombed.

22. Formation of fluviatile strata.—There is a circumstance connected with these facts which it is necessary here to consider. The quantity of water in streams and rivers varies considerably at different periods of the year; in the rainy season the rivers are overflowing, and the waters remarkably turbid: consequently the deposits are much greater at those periods than in the summer

months, when the currents are feeble, and the rivers shallow. In that part of the stream affected by the tides, there is also a constant flux and reflux of the waters, and from this cause the sediments must, to a certain degree, be periodical. Accordingly we find the silt and sand disposed in *strata* or layers, from the partial consolidation of the surface of one bed of mud, before the superincumbent layer was precipitated upon it. Thus wherever a fresh break takes place in a bank of consolidated silt, in a delta, as for example in that of the Nile, it is easy to trace the deposits of each successive year, by means of the lighter earth on the top of each. When a portion is taken into the hand, it separates into layers; and on closely examining the edges of these, very delicate thin lines are perceptible, showing a laminated structure, like those observable in the coal-shales. Judging from these layers, the annual deposits from the Nile appear to vary considerably, but the average thickness is little more than a quarter of an inch.*

Where a river terminates in an extensive estuary, the sea throws over the layer of mud brought down by the river, a covering of sand; and frequently these alternate with the greatest regularity, the receding of the tide allowing the fresh water to deposit its mud, and the advance of the sea discharging sand and marine exuviæ over the surface.

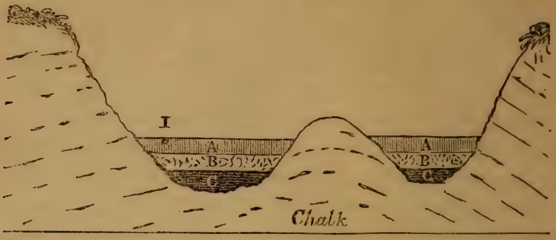
23. Ripple-marks.—And here we may notice another phenomenon. Every one must have observed, when walking by the banks of a river at low water, or on the sands of the sea-shore, that when the water has been agitated by the wind, the surface of the mud, or sand, is undulated, or furrowed over by the rippling of the waves, the marks presenting various appearances, according to the force and

* Letter to Professor Silliman from an American who visited Egypt in 1834.

direction of the currents. Frequently, too, worms and molluscous animals crawl over and mark the surface with meandering lines, and ridges; and these varied characters on the sand are preserved, if a thin layer of mud happens to be deposited over them before the next advance of the waves. I shall have occasion to refer to these appearances hereafter. We may also remark that certain kinds of mollusca, or shell-fish, can only live in fresh water; others are confined to the sea; while a third class is restricted to the brackish waters of estuaries; accordingly, in the deposits under consideration, the river and estuary species are abundant, while the marine only occur as stragglers, and are comparatively rare. Land plants, and those which affect a marshy soil, as the equiseta, or mare's-tails, reeds, rushes, &c. are likewise often accumulated in such quantities as to form beds of peat.

24. Lewes Levels.—It will serve to impress the subject more forcibly upon our minds, if we refer to some local example of fluvio-marine deposits: and from its immediate vicinity to Brighton, I select that which occurs in the valley of the Ouse, near Lewes, which is one of several estuaries whence the sea has retired within the last eight or ten centuries. This tract is about eight miles in length from north to south, and varies in breadth from half a mile to two miles and a half. The valley is bounded by an amphitheatre of chalk hills, into which the river enters through a gorge of the Downs on the north, near Offham, and pursuing a tortuous course, flows between the towns of Lewes and The-Cliff, and discharges its waters into the sea at Newhaven. This alluvial plain is called *Lewes Levels*, and is here and there flanked on the east and west by headlands, and ancient sea-cliffs; while a few insular mounds of chalk rise up through the fluviatile deposits, that have been accumulating during a long period of time. *Lign.* 7, represents a section of the valley of the Ouse, from east to west.

Here we have a depression (or *basin*, as it is termed by geologists) of chalk strata, partially filled up by layers of



LIGN. 7.—SECTION ACROSS LEWES LEVELS.*

A. A. Silt, with river shells; B. B. Clay, with river and marine shells; C. C. Deposit with marine shells only.

indurated mud or silt, the surface of which is clothed with verdure; the bed of the river (I) is situated near the eastern chalk cliffs. By numerous sinkings through the soil, carried from the surface down to the chalk bottom, and the depth of which varied from fifteen to thirty feet, the deposits have been ascertained to be as follow:—

1. Bog-earth and peat, about five feet in thickness: formed of decayed twigs and leaves of hazel, oak, birch, &c. inclosing trunks of large trees.
2. (A. A.)—Blue clay, or indurated mud, containing several species of fresh-water shells, like those which now inhabit the river and ditches; with numerous *indusiæ*, or cases of the larvæ of a species of May-fly (*phryganeæ*) commonly termed caddis-worms. Bones of horses and deer have been found in the lower part of this bed.

---

* A *geological section* represents the internal structure of the earth on any given line, in a vertical direction; and is either, 1, *natural*, as seen in cliffs, precipices, &c.; 2, *artificial*, as in quarries, tunnels, and other excavations; or, 3, *theoretical*, when constructed from a combination of observations on the position of the strata in various distant localities.

3. (B. B.)—Clay, containing fresh-water shells, with an intermixture of existing marine species, as the common cockle, (*cardium edule,*) tellina, &c.
4. (C. C.)—Blue clay, inclosing marine shells, viz. cockles, mussels, &c. without any intermixture of fluviatile species. In this deposit a skull of the Narwhal, or sea-unicorn (*Monodon monoceros*), and of the Porpoise have been discovered.

From the nature of these sediments we learn that this valley was once an arm of the sea, and that the following sequence of physical changes has taken place :—

First, there was a salt-water estuary, inhabited by marine shell-fish of the same species as those now existing in the British Channel, into which cetacea occasionally entered.

Secondly, the inlet grew shallow, the water brackish, and marine and fresh-water shells were mingled in its blue argillaceous sediment.

Thirdly, the shoaling continued till fresh-water so much predominated, that fluviatile shells, and aquatic insects, could alone exist.

Fourthly, a peaty swamp was formed, by the drifting of trees, and plants, from the forest of Andreadswald, which formerly occupied the entire Wealds of Sussex and the adjacent counties; and terrestrial quadrupeds were occasionally imbedded in the morass.

Lastly, the soil being inundated by land-floods at distant intervals only, became an oozy marsh, which has been gradually converted into a fertile tract of country.

Such are the natural changes which the river valley of the Ouse has undergone, as shown by the character of the deposits which partially fill up this depression in the chalk; and historical records confirm the geological evidence.* What further transmutations the plain of Lewes Levels is destined to undergo cannot be foretold. It may be, that

* See "A Day's Ramble in and about the Ancient Town of Lewes," 1 vol. 8vo. 1846, by the Author.

some change in the relative level of the land and water along the Sussex coast will again convert the Levels into an arm of the sea, and the town of Lewes be once more a port. On the other hand, the physical agents of terrestrial change may lie dormant, and man, with the mighty powers of nature over which science has given him control, may include this alluvial plain in the grand line of communication that shall link together the metropolitan cities of France and of England, and ere another century have passed away, these now verdant pastures may be covered with towns and cities, swarming with busy communities of the human race.

25. REMAINS OF MAN IN MODERN DEPOSITS.—But the sediments in the river valleys often contain not only bones of deer, horse, boar, and other terrestrial animals, but also human skeletons, which are sometimes found inclosed in coffins of exceedingly rude workmanship; together with canoes,* and other relics of the early inhabitants of our

* *Ancient British Canoe.* In 1835 a canoe was discovered at the depth of several feet in a bed of silt, that filled up an ancient branch of the river Arun, at North Stoke, near Arundel. It was presented, by my noble friend the late Earl of Egremont, to the British Museum. This canoe is nearly thirty-five feet in length, four and a half wide in the centre, three feet three inches broad at one extremity, and two feet ten inches at the other; and is about two feet deep. It is formed of a single trunk of oak, which has been hollowed out and brought to its present shape with great labour: it is evidently the workmanship of a very remote period, and in all probability was constructed by some of the earliest inhabitants of our island, before the use of iron or even brass was known: the original tree must have been fifteen or sixteen feet in circumference. Three projections, left in the interior of the boat, appear to have been designed for seats; it is manifest therefore that the persons who constructed this vessel were unacquainted with the art of forming boards. This canoe is so similar to some of those which were fabricated by the aborigines of North America, when first visited by Europeans, that we can have no hesitation in concluding that it was constructed in a similar manner; namely, by charring

island. This human skull was dug up at a great depth in the blue silt of Beeding Levels ; it was inclosed, together with the other bones of the skeleton, in a coffin of oak, which was evidently of high antiquity, being formed of four rude planks, or rather hewn trunks of trees, held together by oaken pegs. The skull is of a dark bluish-brown colour, like the bones of deer and horse found in similar deposits, an appearance attributable to an impregnation of iron ; when first dug up, the interstices of the bones were filled with blue phosphate of iron. The state of the teeth is remarkable, for the crowns of the incisors are worn down almost flat, although the individual must have been in the prime of life ; a fact which seems to indicate that grain, and other hard substances, constituted his customary food.

26. Peat bogs.—Before proceeding to the next subject, I will advert to those extensive accumulations of vegetable matter called Peat Bogs. These are morasses, covered with successive layers or beds of mosses, reeds, equiseta, rushes, and other plants that affect a marshy soil ; and in particular of a kind of moss, the *sphagnum palustre*, which frequently forms a large proportion of the entire mass. The beds of peat are annually augmented by the peculiar mode of increase of the moss, which throws up a succession of shoots to the surface, while the parent plants decay, and add a new layer of soil.

The peat bogs of Ireland are of great extent : one of the mosses on the banks of the Shannon is between two and three miles in breadth, and fifty in length. Mr. Lyell remarks, that most of the peat-mosses of the North of Europe occupy

such portions of the tree as were to be removed, and scooping them out with stone instruments : no doubt this canoe belongs to the same period as the flint and stone instruments called *celts*, which are found in the tumuli on the South Downs.

the areas of ancient forests of oak and pine ; and that the fall of trees from the effect of storms, or natural decay, by obstructing the draining of a district, and thus giving rise to a marsh, is the origin of most of these deposits ; mosses, and other marsh plants, spring up, and soon overwhelm and bury the prostrate trees ; hence the occurrence of trunks and branches of oaks, firs, &c. with their fruits. De Luc states, that the sites of many of the aboriginal forests on the continent are now covered by mosses and fens, and that many of these changes are attributable to the destruction of the woods by the Romans.

A remarkable circumstance relating to peat bogs must not be omitted, namely, the occasional occurrence of the bodies of men and animals, in a high state of preservation, at a great depth. In some instances the bodies are converted into a fatty substance resembling spermaceti, and which is called *adipocire*.

27. COAL IN PEAT.—A fact of considerable geological interest is the occurrence of coal in peat bogs, since it proves that the conversion of vegetable matter into a mineral, the origin of which, but a few years since, was deemed questionable, takes place at the present time, when circumstances are favourable for the production of the bituminous fermentation. In Limerick, in the district of Maine, one of the States of North America, there are peat bogs of considerable extent, in which a substance exactly similar to *cannel coal* is found at the depth of three or four feet from the surface, amidst the remains of rotten logs of wood and *beaver-sticks:* the peat is twenty feet thick, and rests upon white sand. This coal was discovered on digging a ditch to drain a portion of the bog, for the purpose of obtaining peat for manure.* The substance is a true bituminous coal, containing more bitumen than is found in

* Dr. Jackson, on the Geology of Maine.

any other variety.* Polished sections of the compact masses exhibit the peculiar structure of coniferous trees, and prove that the coal was derived from a species allied to the American fir. It has probably been formed by the chemical changes supervening upon fir-balsam, during its long immersion in the humid peat; the circumstances under which it was placed being most favourable for that process to take place, by which, as we shall show hereafter (see *Lecture* VI.), vegetable matter is converted into coal. In the Chatham Islands, Dr. Dieffenbach observed a bed of peat, in which were layers closely resembling coal, and possessing a lustrous appearance and conchoidal fracture; while in other parts of the same layers the transition to true peat was evident.

28. Subterranean forests.—Independently of the trees imbedded in peat bogs and morasses, there are also found entire forests buried deeply in the soil; the trees having their roots, trunks, branches, fruits, and even leaves, more or less perfectly preserved. Numerous accumulations of this kind have been discovered on the coasts of England, occupying low alluvial plains, that are still subject to periodical inundations.† The trees are chiefly of the oak, hazel, fir, birch, yew, willow, and ash; in short, almost every kind that is indigenous to this island occasionally occurs. The trunks, branches, &c. are dyed throughout of a deep ebony colour by iron; and the wood is firm and heavy, and occasionally fit for domestic use; in Yorkshire, timber of this kind is sometimes employed in the construction of houses.

29. Geological effects of the ocean.—While the mountains, valleys, and plains of the interior of a country,

* An analysis of 100 grains gave the following results:—*Bitumen*, 72; *Carbon*, 21; *Oxide of Iron*, 4; *Silica*, 1; *Oxide of Manganese*, 2; = 100.

† See Illustrations of the Geology of Sussex, p. 288.

are undergoing slow but perpetual destruction by the combined effects of atmospheric agency, and of running water, the coasts, cliffs, and shores, are exposed to destruction from the action of the waves, and the encroachments of the sea. When the land presents a high and rocky coast, the waves, by their incessant action, undermine the cliffs, which at length fall down, and cover the shore with their ruins. The softer parts of the strata, as the chalk, limestone, marl, clay, &c. are rapidly disintegrated and washed away; while the more solid materials are broken, and rounded, by the continual agitation of the water, and give rise to those accumulations of shingle and sand which skirt the base of the sea-cliffs, and serve, in some situations, to protect the land from further encroachments. But when the cliffs are entirely composed of soft substances, their destruction is very rapid, unless artificial means be employed for their protection; which, however, in many instances are wholly ineffectual.

The encroachments of the ocean upon the land effected by this agency, often give rise to sudden and extensive inundations, and the destruction of whole tracts of country. Along the Sussex coast the inroads of the sea have been noticed in the earliest historical records; and the site of the ancient town of Brighton has been entirely swept away, the sands, and the waves, now occupying the spot where the first settlers on these shores fixed their habitations.* On low and sandy coasts, the waves drive the loose and lighter materials towards the land; and the drifted sand, becoming dry at the reflux of the tide, is carried by the wind inland, and in some situations is accumulated in such quantities as

* In my "Fossils of the South Downs," and "Geology of the South-East of England," will be found some interesting historical notices of the destruction of the Sussex coast by the inroads of the sea. These have been copied almost verbatim into several geological works, without acknowledgment or reference.

to form ranges of hills, which in their progress overwhelm fertile tracts, and engulf churches, and even entire villages. These sand-banks or downs, loose and fluctuating as they are in their first stage of advancement, become under certain circumstances stationary, and are then converted into solid stone, by a process which we shall presently explain.

30. THE BED OF THE OCEAN.—But the production of beach, gravel, and sand, on the shores, and the drifting of sand inland, are effects far less important than those which are going on in the profound depths of the ocean. In the tranquil bed of the sea, the finer materials, that were held in chemical or mechanical suspension by the waters, are precipitated and deposited, enveloping and imbedding shells, corals, fishes, &c. together with the remains of such terrestrial animals and vegetables as may be floated down by the streams and rivers. And, in the beautiful language of Mrs. Hemans,—

"The depths have more! What wealth untold
Far down and shining through their stillness lies!
They have the starry gems, the burning gold,
Won from a thousand royal argosies!

"Yet more—the depths have more! Their waves have rolled
Above the cities of a world gone by—
Sand hath filled up the palaces of old,
Sea-weed o'ergrown the halls of revelry.

"To them the love of woman hath gone down,
Dark flow their tides o'er manhood's noble head,
O'er youth's bright locks, and beauty's flowery crown."—

Yes! in these modern deposits, the remains of man, and of his works, must of necessity be continually engulfed, together with those of the animals which are his contemporaries.

Of the nature of the present bed of the ocean, we can of course know but little from actual observation. Soundings, however, have thrown light upon the deposits now forming in those depths which are accessible to this mode of investigation, and shown that in many parts immense accumulations of shells and corals, intermixed with sand, gravel, and mud, are going on. Donati ascertained the existence of a compact bed of shells, 100 feet in thickness, at the bottom of the Adriatic, which in some parts was converted into marble. In the British Channel, extensive banks of sand, imbedding shells, crustacea, &c. are in the progress of formation. This specimen, which was dredged up a few miles off Brighton, is an aggregation of sand with recent marine shells, oysters, mussels, limpets, cockles, &c. and minute corallines;* and this example, from the coast of the Isle of Sheppey, consists entirely of cockles (*Cardium edule*), held together by conglomerated sand.†

In bays and creeks, bounded by granitic rocks, the bottom is found to be composed of micaceous and quartzose sand, consolidated into what may be termed regenerated granite. Off Cape Frio, on the Brazilian coast, solid masses of this kind were formed in a few months, and in them were found imbedded, dollars and other treasures from the wreck of a vessel, the *Thetis*, to recover which an exploration by the diving bell was undertaken.

31. EFFECTS OF CURRENTS.—The distribution over the bottom of the sea of the detritus brought down by rivers and streams, and of the materials worn away by the action of the waves on the shores, is principally effected by the influence of currents, which, from their regularity, permanency, and extent, may be considered as the rivers of the ocean. To this agency I can but briefly allude, and shall restrict my remarks to the Gulf-stream, which is the great current that transports the waters, and the temperature of

* Medals of Creation, vol. i. p. 375, *lign.* 87.
† Ibid. p. 377, *lign.* 88.

the tropical regions, into the climates of the north. From the mouth of the Red Sea a current about fifty leagues in breadth sets continually towards the south-west; doubling the Cape of Good Hope, it assumes a north-west direction, and in the parallel of St. Helena, its breadth exceeds 1000 miles; then taking a direction nearly east, it meets in the parallel of 3° north, along the northern coast of Africa, with a stream from the north; entering the Gulf of Florida, the united currents are reflected and form the Gulf-stream, which, passing along the coast of North America, stretches across the Atlantic to the British Isles. At the parallel of 38°, nearly 1000 miles from the Straits of Bahama, the water of the stream is ten degrees warmer than the air. The course of the Gulf-stream is so fixed and regular, that nuts and plants from the West Indies are annually drifted to the western islands of Scotland. The mast of a man-of-war, burnt at Jamaica, was driven ashore several months afterwards on the Hebrides, "after performing a voyage of more than 4000 miles under the direction of a current, which, in the midst of the ocean, maintains its course as steadily as a river upon the land."* The quantity and variety of detritus transported by such currents must be immense, and we therefore need not wonder at frequently finding the productions of different climates associated together in a fossil state.

32. Icebergs and glaciers. From the consideration of the dynamical powers of water as a fluid, we pass to the examination of its effects when consolidated by congelation. The character of the regions of eternal ice in the Arctic circle—the floating islands and mountain ranges composed of rock-ice, which everywhere threaten with impending destruction the intrepid mariners who penetrate the desolate polar seas—the removal and transport of

* Playfair's Works, edition 1822; vol. i. p. 414.

immense masses of rocks and boulders by drifting ice-floes, and the distribution of these materials in the bed of the ocean, or on the land, as the congealed water gradually melts as it approaches a milder climate—are phenomena so familiar to the English reader, from the graphic accounts which have emanated from our naval officers engaged in the arduous service of the voyages of discovery, undertaken during the present century, that it will not be necessary to dwell upon the subject.

Glaciers are sheets of ice, which form upon the tops and in the clefts and valleys of mountains, that attain such an elevation as to be within the regions of eternal snow. They are not inaptly termed, by that most charming of all philosophical travellers, Mr. Darwin, gigantic icicles. The lowest limit to which glaciers extend, depends, of course, on the height of the line of perpetual congelation, which varies in different latitudes, and is also modified by the configuration of the land. In the Alps the traveller enters the region of eternal snow at a height of from 3000 to 7000 feet; while in South America, under the equator, the snow line is equal to that of the summit of Mont Blanc.* In the Alps there are vast table-lands, of from 100 to 300 square miles, composed of solid ice, from which descend enormous masses, that slowly glide towards the lower regions, bearing with them innumerable fragments of rock. So soon as these glaciers reach the lowest limit of perpetual congelation, they melt, and the fragments of rock they contain are deposited, and form mounds and ridges of stones of all sizes, which are called *moraines;* these remain after all vestiges of the agent which produced them have disappeared. The difference in the character of the materials brought down by torrents and by glaciers is very manifest: for the former give rise to beds of gravel; the latter to ridges or

* Humboldt.

heaps of boulders. The movement of the glacier from the mountain top, arises from the softened state of the layer of ice in contact with the surface of the earth on which it rests; for the beautiful experiments of Professor Forbes have shown that ice moves upon the principle of a tenacious or viscous fluid; that is, by gravitation on an inclined surface. The rocks forming the bases of the glaciers, and the sides of the valleys they have traversed, are more or less polished and grooved, from the passage of angular masses of rock when impacted in the moving ice: the grooves being in the direction of the movement of the glacier.*

From careful observations on these appearances, M. Agassiz has established characters by which, in countries where the hills are at the present time far below the snow line, evidence of former glaciers of great extent has been obtained. Many indications of ancient glaciers are supposed to occur in England and Scotland; and the accumulations of drifted materials, containing large angular blocks, and disposed in long banks and ridges, and the grooves and scratches on the surface of the rocks forming the sides of valleys and slopes of hills, which lead off from these supposed moraines, are regarded by some geologists as unequivocal proofs of a great extent of glaciers in these islands at a comparatively recent period: and the drift, boulders, and superficial alluvial debris, are attributed, in a great measure, to the agency of either icebergs or glaciers. But the sweeping conclusion of M. Agassiz and others, that the whole of Europe was once covered with ice, should be received with much hesitation; and it is to be regretted that the term "*glacial period*" has been admitted into geological nomenclature.

* See "Etudes sur les Glaciers," par M. Agassiz; Neuchatel, 1840; and the Works and Memoirs of Prof. Forbes (in the Philos. Trans.), on the same subject.

The former existence of limited glaciers in some parts of Great Britain, perhaps accompanied with a lower climatorial temperature than now prevails, appears to me the extent to which, in the present state of our knowledge, the glacial theory can be admitted as a *vera causa*, in our attempts to interpret the origin of the drift of the British islands. It may, however, be well to state, that if an elevation of the European continent to the amount of but 2000 feet were to take place, a great part of its surface would be covered with glaciers and perpetual snow, and cease to be habitable.

33. Incrusting springs.—The phenomena hitherto considered, are referable to the mechanical action of water; and the effect has been disintegration, and destruction, in the first instance, and in the second the accumulation of sediments in water-courses, and their transport into the bed of the sea. We must now refer to an operation of a totally different character—the power possessed by streams, as clear and sparkling as poet ever feigned or sung, of consolidating loose materials, of converting porous strata into solid stone, and of filling up their own channels by the deposition of calcareous matter.

That most fresh water holds a certain proportion of carbonate of lime* in solution, is well known; and also that changes of temperature, and certain other causes, will occasion the calcareous earth to be in part or wholly precipitated. The *fur*, as it is called, that lines a boiler which has been long in use, affords a familiar illustration of this fact. At the temperature of 60°, lime is soluble in 700 times its weight of water, and if to the solution a small

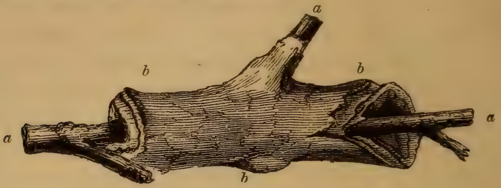
* *Carbonate of lime* consists of lime in combination with carbonic acid gas, which is a most abundant natural product. This gas is irrespirable, and when pure, will immediately suffocate an animal immersed in it, and extinguish flame.

portion of carbonic acid be added, carbonate of lime is formed, and precipitated in an insoluble state. If, however, the carbonic acid be in such quantity as to supersaturate the lime, it is again rendered soluble in water; and it is thus that carbonate of lime, held in solution by an excess of fixed air, not in actual combination with the lime, but contained in the water and acting as a menstruum, is commonly found in all waters. An absorption of carbonic acid, or a loss of that portion which exists in excess, will therefore occasion the calcareous earth to be set free, and precipitated on any substances in the water, such as stones, twigs, and leaves of trees, &c. Some springs contain so large a portion of calcareous earth when they first issue from the rocks, and so speedily throw it down in their course, that advantage has been taken of the circumstance to obtain incrustations of various objects, as leaves, branches, baskets, nests with eggs, and even old wigs. The incrusting springs of Matlock and other places in Derbyshire are celebrated for such productions.* The substance deposited is termed tufa, or travertine; and in Italy, and many other countries, it constitutes extensive beds of concretionary limestone, which is often of a crystalline structure. The Cyclopean walls and temples of Pæstum, are formed of travertine. At the baths of San Filippo, in Tuscany, where the waters are highly charged with tufa, this property is applied to a very ingenious purpose. The stream is directed against moulds of medallions and other bas-reliefs, and beautiful casts are thus obtained.

34. Incrustations.—As specimens of this kind are commonly, but erroneously, termed petrifactions, it will be necessary to explain their real nature. We have before us several incrustations from various places: baskets of shells,

* An account of the incrusting springs at Matlock is given in "Medals of Creation," vol. ii. p. 940.

and nests with eggs, from Derbyshire; a bird, from Knaresborough, in Yorkshire; and twigs and branches partially incrusted, from Ireland, Russia, &c.



LIGN. 8.—A TWIG INCRUSTED WITH TUFA.
a, a, a, Extremities of the twig unchanged; *b, b, b,* the tufaceous crust.

I need scarcely observe, that on breaking such specimens, we find the inclosed substances to have undergone no change but that of decay. In this incrustation (*Lign.* 8) the twig, which is exposed in several places, is not permeated by stony matter, but is withered, and brittle. Now, a true *petrifaction* is altogether of a different nature, the substance being more or less completely mineralized; if we break it, we find that every part of its structure has undergone a change. Wood, for instance, is often entirely transmuted into flint or chalcedony, and may be cut so thin, that with a powerful lens the ramifications of the vessels and the structure of the tissues may be seen, and from their form, and disposition, we may determine the particular kind of tree to which the specimen belonged, although it may have been enshrined in the stone for ages. When bone is petrified, the same phenomena are observable; the most delicate parts of the internal structure are preserved, and all the cells are filled up with calcareous spar, which is oftentimes of a different colour from that of the walls of the cells, and thus a natural anatomical preparation of great beauty and interest is formed.

35. Lake of the Solfatara.—One of the most celebrated travertine springs is the lake of the Solfatara, which lies in the Campagna between Rome and Tivoli, and is fed by a stream of thermal water that flows into it from a neighbouring pool. The water is of a high temperature, and saturated with carbonic acid gas, which, as the water cools, is constantly escaping, and keeping up an ebullition on the surface. The stream that flows out of the lake fills a canal, which is conspicuous at a distance, from the line of vapour that emanates from the water. The formation of travertine is so rapid, that not only the vegetables and shell-fish are surrounded and destroyed by the calcareous deposit, but insects also are frequently incrusted. In the beautiful specimens of travertine before us from the Solfatara, vegetable impressions are distinctly seen ; the cavities in these masses have been produced by the decomposition of the vegetable matter.*

A considerable number of the edifices of both ancient and modern Rome, are constructed of travertine obtained from the quarries of Ponte Luccano, which has clearly originated from a lake of this nature. Pæstum is also built of calcareous tufa, derived from similar deposits. "The waters of these lakes," says Sir Humphry Davy,† "have their rise at the foot of the Apennines, and hold in solution carbonic acid, which has dissolved a portion of the calcareous rocks through which it has passed ; the carbonic acid is dissipated by the atmosphere, and the marble, slowly precipitated, assumes a crystalline form, and produces coherent stone. The acid originates in the action of volcanic fires on the calcareous rocks of which the Apennines are composed, and carbonic acid being thus evolved, rises to the source of the springs, and gives them their

* See Appendix B.

† Consolations in Travel; or, the Last Days of a Philosopher.

impregnation, and enables them to dissolve a large quantity of calcareous matter."

36. Marble of Tabreez.—In Persia, a beautiful transparent limestone, called Tabreez marble, is formed by deposition from a celebrated spring near Maragha, where the whole process of its formation may be seen. In one part the water is clear; in another dark, muddy, and stagnant; in a third it is very thick, and almost black; while in the last stage it is of a snowy whiteness. The petrifying pools look like frozen water; a stone thrown on them breaks the crust, and the water exudes through the opening; and in some states the process has proceeded so far as to admit of walking on the surface of the lake. A section of the stony mass resembles an accumulation of sheets of paper, being finely laminated; and such is the tendency of this water to solidify, that the very bubbles on its surface become hard, as if they had been suddenly arrested, and metamorphosed into stone.*

37. Stalactites, and Caverns.—By the infiltration of water through limestone rocks, into fissures and cavities, sparry concretions are produced on the roofs, sides, and floors of caverns. The concretionary masses which are dependent from the roof like icicles, are called *stalactites;* those which form on the floor, from the droppings of the water, are termed *stalagmites;* and when, as frequently happens, the two unite, a singularly picturesque effect is produced; the caves appearing as if supported by pillars of great beauty and variety.† Sometimes a linear fissure in the roof, by the direction it gives to the dropping of the lapidifying water, forms a perfectly transparent curtain or partition. A remarkable instance of this kind occurs in a cavern in North America, called Weyer's Cave, which is situated in the limestone range of the Blue Mountains.‡

* Morier's Travels. † Appendix C. ‡ Appendix D.

There are also many caverns in England, celebrated for the variety and beauty of their sparry ornaments ; those of Derbyshire are well known.

The Grotto of Antiparos in the Grecian Archipelago, not far from Paros, has long been celebrated. The sides and roof of its principal cavity are covered with immense incrustations of calcareous spar, which form either stalactites, depending from above, or irregular pillars rising from the floor. Several perfect columns reaching to the ceiling have been formed, and others are still in progress, by the union of the stalactite from above, with the stalagmite below. These being composed of matter slowly deposited, have assumed the most fantastic shapes; while the pure, white, and glittering spar, beautifully catches and reflects the light of the torches of the visitors to this subterranean palace, in a manner which causes all astonishment to cease at the romantic tales told of the place—of its caves of diamonds, and of its ruby walls ; the simple truth, when deprived of all exaggeration, being sufficient to excite admiration and awe.*

The specimens before us will serve to illustrate these remarks: these long stony icicles are from the Isle of Portland; and these minute straws of spar are from an archway near the Chain Pier, and have been formed by the infiltration of rain through the superincumbent bed of calcareous rock. This mass of pebbles, held together by calc-spar, and containing bones and teeth of some ruminant, is from the cliffs at Kemp Town, and shows, that in periods very remote, the same process was in action along the Sussex shores. These beautiful slabs of marble are portions of stalagmites, from St. Michael's Cave, Gibraltar;

* An admirable model of part of the celebrated Cave of Adelsberg, described by Sir H. Davy, as the habitation of the *Proteus,* may be seen in the Colosseum in the Regent's Park.

and this large conical mass, which has been cut through and polished to show its structure, was dug up on the summit of Alfriston Hill, in Sussex, and must have been formed in some fissure or cavern in the chalk, of which no traces now remain.

38. CONSOLIDATION OF LOOSE SAND, &c.—The changes effected by this process in strata composed of loose materials, are of still greater importance; for by an infiltration of crystallized carbonate of lime, sand is converted into sand-stone,—fragments of soft chalk are transmuted into a solid rock, as in the Coombe-rock of Brighton,—and accumulations of beach, and gravel, into a hard conglomerate, as in this example of the ancient shingle bed of the cliffs, at Rottingdean;—shells, into a building stone, as in this mass from Florida,—and the detritus of shells and corals, into limestone, as in these specimens from Bermuda. By this agency, the bones of animals are permeated with calcareous spar, and their medullary cavities lined with crystals of carbonate of lime: and clay, which has cracked by drying, has its fissures filled up, and becomes consolidated into those curious masses, called *septaria*, which, when polished, form the beautiful table-slabs for which Weymouth is celebrated.

39. DESTRUCTION OF ROCKS BY CARBONIC ACID GAS.—Although, in the instances above cited, water, by its combination with carbonic acid, occasions the solidification of loose and porous beds of detritus, yet the effect of this gas on certain rocks is that of disintegration; for by its solvent influence on the felspar, granite itself is reduced to a friable state, the quartz and mica, which with felspar constitute that rock, being set at liberty. The disintegration of granite, is a striking feature throughout extensive districts in Auvergne, especially in the neighbourhood of Clermont. In the ancient shingle of the cliffs at Kemp Town, near Brighton, blocks of granite occur which may be crumbled

to pieces between the fingers. I have already shown you masses of pebbles held together by calcareous spar, from the same locality; we have, therefore, examples in that ancient bed, both of the conservative and disintegrating effects of carbonic acid—cementing the loose beach into solid blocks by calcareous depositions, and when in a gaseous state, or combined with water, dissolving the granite by its action on the felspar.

40. Carbonic acid gas in caves.—The escape of carbonic acid gas through fissures, into mines, wells, and caverns, is of frequent occurrence, and as the specific gravity of this gas is greater than that of atmospheric air, it forms an invisible pool at the bottom of these cavities, and its presence is seldom suspected, till shown by its deleterious effects; hence fatal accidents often happen to well-diggers and excavators from this cause;* it is called choke-damp by miners.

The *Grotto del Cane*, near Puzzuoli, four leagues from Naples, has for centuries been celebrated on account of the constant evolution, from fissures in the rock, of carbonic acid gas in combination with much aqueous vapour, which is condensed by the coldness of the external atmosphere. The floor of the cavern being lower than the entrance, the gas is spread over the bottom like a pool of water, and the upper part is free from any noxious vapour; the suffocating effects of the carbonic acid is, therefore, not felt by any creature whose organs of respiration are above the level of this mephitic lake; but if a dog, or other small animal, enters the cave, it instantly falls senseless, and would expire if not speedily removed: the name of the cave is derived from the experiment being often made on dogs, for the amusement of visitors.† It is im-

* A few pounds of quicklime thrown into a well, quickly absorbs the carbonic acid gas.

† See Sandys' Travels; London, 1637.

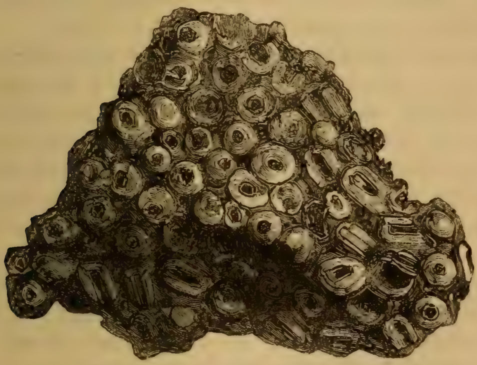
possible to fire a pistol at the bottom of the cavern ; for, though gunpowder may be exploded even in carbonic acid by the application of a heat sufficient to decompose the nitre, and consequently to envelope the mass in an atmosphere of oxygen gas, yet the influence of a mere spark from steel produces too slight an augmentation of temperature for this purpose.*

41. CONSOLIDATION BY IRON.—Water charged with a large proportion of iron, acts an important part in the consolidation of loose materials, converting sand into iron-stone, and beach or shingle into a ferruginous conglomerate. On Clapham Common, and in other places in the vicinity of London, large blocks of a very compact breccia occur, being masses of chalk-flints more or less broken and rolled, cemented together by an infiltration of iron. In this example of a horse-shoe firmly impacted in a mass of pebbles and sand, from the sea-beach at Eastbourn, the cement which binds the mass is derived from the iron. Nails are frequently found in the centre of a nodule of hard sandstone formed by this process ; the nail having supplied the water with the material by which the surrounding sand has become concreted into stone. I have here a cannon ball imbedded in the centre of a nodule of iron-stone, in which are several oyster shells : this specimen was dredged up off the Sussex coast, and has evidently been consolidated by the partial oxidation of the iron.

In this mass of breccia, which has been produced by a like process, are two silver pennies of Edward I ; it was found in 1832, at a depth of ten feet in the bed of the river Dove, in Derbyshire. The coins are presumed to be part of the treasures contained in the military chest of the Earl of Lancaster, which was lost in this stream in 1322 ; the soldiers being alarmed by a sudden

* Daubeny on Volcanoes.

panic, threw the chest with all its contents into the Dove, and it was never recovered. This specimen, with many others, was dug up in deepening the bed of the river; more than five centuries have, therefore, elapsed since its immersion.* A particular account of this discovery is given in the Penny Magazine for November, 1834; many thousand silver coins, comprising a great variety of the English, Irish, and Scotch coinage, of the 13th and 14th centuries, were found imbedded in a hard conglomerate.



LIGN. 9. — FERRUGINOUS CONGLOMERATE, COMPOSED OF BEADS AND KNIFE-BLADES; FROM A STRANDED SHIP, OFF HASTINGS.

This curious specimen (*Lign* 9), for which I am indebted to my friend, George Grantham, Esq. of Barcombe Place, Sussex, was obtained from a Dutch vessel, that was stranded off Hastings a century ago, and became imbedded in silt and sand. It is a conglomerate of glass beads, knives, and sand; the cementing material having been derived from the oxidation of the blades. From the bed of

* See the Vignette of the Title-page.

the Thames, large masses of a firm conglomerate are occasionally dredged up, in which Roman coins, and fragments of pottery, are imbedded ; the stone being formed of sand and clay solidified by ferruginous infiltration.

These specimens of oxide of iron were dug up in a marshy soil, near Bolney, in Sussex, and are of the same nature as the substance called bog-iron ore, which so frequently occurs in peat. Specimens of bog-iron are not uncommon in the superficial loam and gravel of the south-east of England. The ebony colour of the woods from Ireland, which we have already examined, has been derived from an impregnation of iron.

The consolidation of sand, gravel, and other detritus, by this agency, is taking place everywhere ; on the shores of the Mediterranean ; on the coasts of the West India Islands, and of the Isle of Ascension ; and on the borders of the United States ; thus the remains of man, at Guadaloupe—of turtles, in the Isle of Ascension—of recent shells, and bones of ruminants, at Nice—of ancient pottery in Greece—and of animal and vegetable substances, in our own country, have become imbedded and preserved.

I now proceed to notice a few instances of these simple but important operations, by which much of the solid crust of the globe is continually being renewed.

42. Recent limestone of the Bermudas. — The shores of the Bermuda Islands afford interesting examples of this class of deposits in different states of consolidation. The sea surrounding the Bermudas abounds in corals and shells ; and from the action of the waves on the reefs, and on the dead shells, the water becomes loaded with calcareous matter. Much of the detritus is transported to a distance, and subsides in the profound depths of the ocean, imbedding the remains of animals and vegetables ; but a great portion is borne by the waves towards the shores, and cast up on the strand in the state of fine earth and sand. This

detritus is blown inland by the winds, and is soon consolidated by the percolation of water, and the infiltration of crystallized carbonate of lime; a fine white calcareous stone is thus formed, which in some localities is sufficiently compact for building. In this rock are numerous shells and corals, of species which inhabit the neighbouring seas; in some instances the large mottled trochus, so well known to collectors both in its natural and polished state, with all its colours preserved, is imbedded in a pure white limestone. In many specimens the colours are faded, and the shells very much in the state of those found in the tertiary strata at Grignon; in others the shelly matter is wanting, but the hard stone retains the forms and markings of the originals. The corals are imbedded in a similar manner; and masses occur in the limestone so like the fossil corals of the oolite of this country, that it requires an experienced eye to detect their real nature.

In a suite of specimens, showing the transition from loose sand to solid rock, we have—

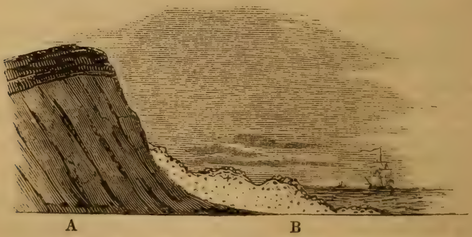
1. Broken shells and corals, retaining their colours.
2. Similar materials, more comminuted and completely bleached.
3. An aggregation of fine sand and white earth, broken shells, and corals.
4. Friable limestone, resembling soft chalk, and composed of comminuted corals, &c.
5. Hard limestone, of similar materials.
6. Compact limestone, enveloping shells and pebbles.
7. A fine indurated limestone, so hard as to be with difficulty broken by the hammer, inclosing a few shells and corals: this stone is employed for building.*

---

* On this bare calcareous rock the coffee-plant finds sufficient support, and is seen in many places growing luxuriantly, its stems shooting out from between the crevices of the stone. In the botanic gardens at Kew are several coffee-plants from Bermuda, growing on blocks of this rock.

In the lakes of Forfarshire, in Scotland,* fresh-water limestone, containing recent shells and aquatic plants, is in progress of formation. In the specimens before us, which were collected by Mr. Lyell, are various species of fresh-water shells, and masses of that common lacustrine plant, the *Chara medicaginula*, beautifully preserved; even the minute seed-vessels of the chara are converted into stone, in precisely the same manner as those in the ancient fresh-water tertiary limestones.† Here then is an example of the formation of a modern lacustrine rock; while, in the recent limestones of Bermuda, we have proof that the sea is at this time forming shelly and coralline rocks, analogous to many of the ancient secondary strata.

43. Fossil human skeletons.—Similar aggregations are in progress along the shores of the whole West Indian Archipelago; and in St. Domingo they have greatly extended the plain of Cayes, where accumulations of conglomerate occur, and in which, at the depth of twenty feet, fragments of ancient pottery have been discovered.



Lign. 10.—Plan of the cliffs at Guadaloupe.
A, Ancient rocks; B, recent limestone, in which human skeletons are found imbedded.

On the north-east coast of the main land of Guadaloupe,

* Geological Transactions, vol. i. p. 73, new series.
† See Geological Excursions round the Isle of Wight, p. 109; Medals of Creation, vol. i. p. 188.

a bed of recent limestone forms a sloping bank, from the steep cliffs of the island to the sea, and is nearly all submerged at high tides. This modern rock is composed of consolidated sand, and comminuted shells and corals of species now inhabiting the adjacent seas: land shells, fragments of pottery, stone arrow-heads, carved stone and wooden ornaments, and human skeletons, are occasionally found imbedded in it. This being the first known undoubted example of the occurrence of human bones in solid limestone, excited great attention; and the fact, simple and self-evident as is its explanation, was made the foundation of many vague and absurd hypotheses.

In most instances the bones are dispersed; but a large slab of rock, in which a considerable portion of the skeleton of a female is imbedded, is preserved in the British Museum, and has been described by Mr. Konig, in a highly interesting memoir, published in the Philosophical Transactions of 1814. The annexed representation (*Lign.* 11) will convey an idea of this celebrated relic, which was detached from the rock at the Mole, near Point-a-Pitre.

In this specimen the skull is wanting, but the spinal column, many of the ribs, the bones of the left arm and hand, of the pelvis, and of the thighs and legs, remain. The bones still contain some animal matter, and the whole of their phosphate of lime. It is remarkable, that the fragments of the skull of this very specimen have recently been purchased for the museum at South Carolina, of a French naturalist, who brought them from Guadaloupe; and they have been described by Professor Moultrie, of the Medical College of that State. These relics consist of portions of the *temporal*, *parietal*, *frontal*, *sphenoidal*, and inferior *maxillary* bones, of the right side of the skull. An entire skeleton was also discovered in the usual position of burial; and another, in a sitting posture, in a softer sandstone. The bodies, thus differently situated, may have belonged to distinct tribes. General Ernouf, who carefully investigated this interesting deposit, conjectured that the presence of the bones might be explained by the circumstance of a battle, and the massacre of a tribe of Gallibis by the Caribs, which took place near this spot, about 120 years ago; for as the bodies of the slain were interred on the sea-shore, their skeletons may have subsequently been covered by sand-

LIGN. 11.—FOSSIL HUMAN SKELETON, FROM GUADALOUPE.
In the British Museum; size of the original, 4 feet 2 inches by 2 feet.

drift, which has since consolidated into limestone. Dr. Moultrie, however, from a rigorous examination, and comparison of the bones of the skull in his possession, is of opinion, that the specimen in the British Museum did not belong to an individual of the Carib, but to one of the Peruvian race, or of a tribe possessing a similar craniological development.

In another skeleton from Guadaloupe, now in the museum of the *Jardin des Plantes*, and represented in the last edition of Cuvier's *Théorie de la Terre*, the figure is bent, the spine forms an arc, and the thighs are drawn up as if the individual were in a sitting posture; a portion of the upper jaw, and the left half of the lower with several teeth, nearly the whole of one side of the trunk and pelvis, and a

LIGN. 12.—HUMAN SKELETON FROM GUADALOUPE.
In the Museum at Paris.

considerable portion of the upper and lower left extremities, are preserved (*Lign.* 12). The stone incloses terrestrial and marine shells; it is evident that the former have been drifted by streams from the interior, and the latter deposited by the sea. In the bed from which this block was extracted, were found teeth of the *Caiman* (a species of crocodile), stone hatchets, and a piece of wood, having rudely sculptured on one side a mask, and on the other the figure of an enormous frog; it is of guaiacum, but has become extremely hard, and as black as jet.*

Human skeletons have also been found in solid calcareous tufa near Santa in Peru. Bones, belonging, it is computed, to some scores of individuals, were discovered imbedded in travertine, containing fragments of marine shells which still possess colour. The bed of stone is covered by a deep vegetable soil, and forms the face of a hill crowned with brushwood and large trees, on the side of the river Santa.†

44. Isle of Ascension.—In the Isle of Ascension, which is a volcanic cone in the midst of the Atlantic, and appears to have been a dome of trachytic rocks, subsequently affording vent to lava currents, a recent deposit of conglomerate is going on. Its coasts are flanked by accumulations of concreted sand with comminuted shells, corals, echini, and fragments of lava. The specimens before us are portions of this modern rock in various states of consolidation; they are composed of corals, which still retain their colour; of shells, more or less broken; and of sand of similar materials; they also contain pebbles of trachytic and glassy lava. The shores of this island are a favourite resort of turtles, which repair thither in immense numbers, and deposit their eggs in the loose sand: the rapid conversion of the coarse calcareous banks into solid stone, occasions the frequent imbedding and preservation of the eggs; and there are specimens in the cabinet of the Geological Society, in which the bones of young turtles, just on the point of

* In the former editions of this work a notice was given of some supposed imprints of human feet on limestone, figured and described in an early volume of the American Journal of Science. These markings have since been carefully examined by Dr. Dale Owen, of New Harmony, and prove to have been sculptured by the Aborigines.

† American Philosophical Transactions for 1828, p. 283.

being hatched, are preserved. The conglomerate of the Isle of Ascension is, as you may observe, principally composed of corals. Here we have another example of a rock formed of the calcareous skeletons of those wonderful forms of organic existence; but it is not my intention in this place to dwell on the geological changes produced by zoophytes in the formation of coral reefs, &c., as the examination of the recent and fossil corals will form the subject of a subsequent Lecture.

45. Drifted sand.—We have already alluded to the encroachments on the land by the drifting of sand-banks thrown up beyond the reach of the tide, and driven by the winds inland; thus effecting the desolation of whole regions by their slow, but certain progress. Egypt instantly presents herself to the imagination, with her stupendous pyramids, the sepulchres of a mighty race of monarchs, and the wonder of the world—her temples, and palaces, once so splendid and massive, as to bid defiance to the ravages of time—her plains, and valleys, formerly teeming with abundance, and supporting a numerous population—now stripped of her ancient glories, her fairest regions depopulated, and converted into arid wastes,—her cities overwhelmed, and prostrate in the dust—and the colossal monuments of her kings, and the temples of her gods, half buried beneath the sands of the Desert!

The drifting of the sands of the Lybian desert by the westerly winds, observes M. De Luc, has left no lands capable of cultivation on those parts of the western bank of the Nile which are not sheltered by mountains; while in Upper Egypt, whole districts are covered by moveable sands, and here and there may be seen the summits of temples, and the ruins of cities which they have overwhelmed. "Nothing can be more melancholy," says Denon, "than to walk over villages swallowed up by the sand of the Desert, to trample under foot their roofs and minarets, and to reflect that yonder were cultivated fields, that there grew trees, that here were the dwellings of men, and that all have now vanished. The sands of the Desert were in ancient times remote from Egypt; and the Oases which still appear in the midst of this sterile region, are the remains of fertile soils which formerly extended to the Nile."*

In the maritime plains and valleys of Peru the same cause is operating slowly, but with unremitting energy; the sea-sands are marching incessantly before the trade wind, and threaten ultimate desolation. The sand has already surmounted the lofty hills which form the southern boundary of the beautiful valley of Lurin, and is flowing down in large waves over the cultivated ground. The same phenomenon is observable on the elevated plain which is called the Tablada, where the tops of the hills appear like Egyptian oases, and whence the sand is pouring down in enormous floods over the sugar plantations of San Juan and Villa, in the valley of Rimac.†

46. Formation of recent sandstone in Cornwall. —On many parts of the shores of Scotland, sand-floods have converted tracts of great fertility into barren wastes; and on the northern coast of Cornwall an extensive district has been covered by drifted sand, which has become consolidated by the percolation of water holding iron in solution, and in some places forms ranges of low mounds, and

* See an Essay on the Moving Sands of Africa, in Professor Jamieson's Translation of Cuvier's Theory of the Earth, p. 375. Sir G. Wilkinson, in his highly interesting work, questions the correctness of these inferences, as to the extent of the sand-floods, and asserts, that at the present time the alluvial soil is on the increase, the deposits from the inundations of the Nile more than counterbalancing the inroads of the sands; and that the land now capable of cultivation in the valley of Egypt is greater than at the time of the Pharaohs.—*Manners and Customs of the Ancient Egyptians*, vol. i. pp. 218—222.

† Blackwood's Edinburgh Magazine for March, 1839.

hills forty feet high. This sandstone is an interesting example of a recent formation, and has been described by Dr. Paris, (the distinguished President of the College of Physicians,) in one of the most graphic and instructive essays on modern deposits that has appeared in this country.* The sand has evidently been drifted from the sea by hurricanes, probably at a very remote period ; it is first seen in a slight, but increasing state of aggregation, on several parts of the shore in the Bay of St. Ives. Around the promontory of New Kaye, the sandstone occurs in various degrees of induration, from that of a friable aggregate, to a stone so compact, as to be broken with difficulty by the hammer, and which is used in the construction of buildings. Upon examining the stone with a lens, it appears to be principally made up of comminuted shells ; and it is worthy of remark, that the shelly particles are frequently spherical, from the previous operation of water ; and some portions of the rock closely resemble the ancient limestone called *oolite*, which will hereafter come under our notice. The rocks upon which the sandstone reposes are clay-slate, and slaty limestone ; and the water effecting their decomposition may have thus obtained the iron, alumina, and other mineral matters by which the loose sand has been converted into sandstone. The infiltration of water thus impregnated is a common and extensive cause of lapidification : at Pendean cove, granitic sand is gradually hardening into breccia, by this process ; and in the island of St. Mary, is becoming indurated by the slow action of this chalybeate.

47. Siliceous deposits.—Silex, or the earth of flint, a combination of the metallic base called silicon with oxygen, is a mineral, which constitutes so large a portion of the rocks and strata, that it is computed to form, either

* Appendix E.

in a pure or combined state, nearly one-half of the solid crust of the globe. The flints from our chalk cliffs, the boulders and gravel on our sea-shores, and the pebbles of agate, quartz, and chalcedony, are well-known examples of the usual varieties of silex.

I scarcely need observe, that this nodule of flint, obtained from a neighbouring chalk-pit, has once been in a soft or fluid state; for there are many sharp impressions of shells, and of spines of an echinus, on its surface.* We have already seen that water impregnated with carbonic acid gas is capable of holding lime in solution, and that travertine, limestone, and other calcareous deposits, have originated from this agency; and although, even in the present advanced state of chemical knowledge, we are but imperfectly acquainted with the process by which any considerable proportion of flint can be dissolved in water, yet we have unquestionable proofs, that the solution of siliceous earth has been effected by natural processes, on a very extensive scale. At the present moment, Nature, in her secret laboratories, is still carrying on a modification of the same process; and of this fact we have remarkable instances in the Geysers of Iceland, and in the Azores, and in New Zealand. A high temperature appears necessary to enable water to hold in solution a large quantity of silex; for we find that the thermal springs of volcanic regions are the only agents by which siliceous deposits and incrustations are at present produced. The difference between the modern siliceous *sinter*, and the flint of the cretaceous strata, appears to be referable to the subaerial deposition of the former, and the submarine formation of the latter.

48. The Geysers of Iceland.—The Geysers, or intermittent boiling fountains, of Iceland, have long been

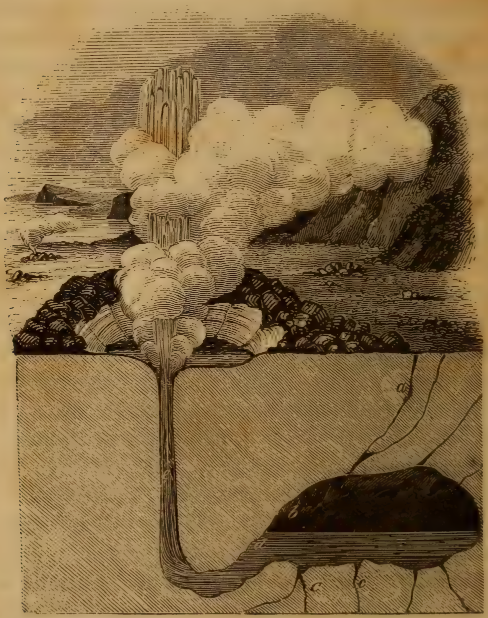
* *See* "Thoughts on a Pebble; or, a First Lesson in Geology." Seventh edition; 1846.

celebrated for possessing this property in an extraordinary degree; holding a large quantity of silex in solution, and depositing it, when cooling, on vegetables and other substances, in a manner similar to that in which travertine is precipitated by the incrusting springs of which we have already spoken. Iceland may be considered as a mass of volcanic matter; the only substances not of igneous origin in the whole island, being deposits of surturbrand, or bituminous wood, in which occur leaves, trunks, and branches of trees, with clay and ferruginous earth. These strata support alternating beds of basalt, tufa, and lava, which form the summit of the hill in which the vegetable remains occur.

The Geysers, of which there are a considerable number, are springs, or rather intermittent fountains, of hot water, which issue from crevices in the lava. A jet of boiling water, accompanied with a great evolution of vapour, first appears, and is ejected to a considerable height; a volume of steam succeeds, and is thrown up with prodigious force, and a terrific noise like that produced by the escape of vapour from the boiler of an engine. This operation continues sometimes for more than an hour, when an interval of repose of uncertain duration succeeds, after which the same phenomena are repeated. If stones are thrown into the mouth of the cavity from which the fountain has issued, they are ejected with violence after a short interval, and again jets of boiling water, vapour, and steam, appear in succession. The eruptions of the "great Geyser," witnessed by Sir G. S. Mackenzie,* were preceded by a sound like the distant discharge of heavy ordnance, and the ground shook sensibly; the sound was rapidly repeated, when the water in the basin, after heaving several times, suddenly

* Travels in Iceland, in the summer of the year 1810, by Sir George Steuart Mackenzie, Bart.

rose in a large column, accompanied by clouds of steam, to the height of ten or twelve feet. The column seemed to burst, and sinking down, produced a wave, which caused the water to overflow the basin. A succession of eighteen



LIGN. 13.—PLAN OF THE GEYSERS OF ICELAND.

or twenty jets now took place, some of which rose to a height of from fifty to ninety feet. After the last eruption, which was the most violent, the water suddenly disappeared, and sunk down the pipe in the centre, to a depth of ten feet; but in the course of a few hours the phenomena were repeated, and with increased energy. The basin of the "great Geyser" is an irregular oval, about fifty-six feet by forty-six, formed of a mound of siliceous deposits about seven feet high; the channel through which the water is ejected being sixteen feet in diameter at the opening, but contracting to ten feet lower down; its perpendicular depth is estimated at sixty feet.

Sir G. S. Mackenzie has proposed an ingenious explanation of these phenomena, which the diagram in the preceding page will serve to illustrate. It is supposed that the water from the surface percolates through crevices (*Lign.* 13, *a*,) into a cavity in the rock (*b*), and heated steam, produced by volcanic agency, rises through fissures in the lava beneath (*c*, *c*). The steam becomes in part condensed, and the water filling the lower part of the cavity (*d*) is raised to a boiling temperature, while vapour under high pressure occupies the upper part of the chasm. The expansive force of the steam becomes gradually augmented, and at length drives the water up the fissure or pipe (*e*), and a boiling fountain with jets of vapour is produced; this continues playing till all the water in the reservoir is expended, when the steam itself escapes with great violence, till the supply is exhausted.*

The siliceous concretions formed by these springs cover an extent of four leagues. M. Eugene Robert states, that this curious formation may be seen passing by insensible gradations from a loose friable state, the result of a rapid deposition, to the most compact and transparent masses, in which impressions of the leaves of the birch-tree, and portions of the stems, are distinctly perceptible, presenting the appearance of the agatized woods of the West Indies. Rushes, and various kinds of mosses, converted into a white siliceous rock, in which the minutest fibres are preserved, also occur; but on the margin of the Geysers, from the

* Travels in Iceland, p. 229.

splashing of the water, the depositions resemble large cauliflowers; and on breaking these masses, vegetable impressions are often discovered. Numerous thermal springs occupy the valley in the interior of the island, in the midst of which the Geysers are situated ; it is evident that these waters rise from deep crevices, in which they have been heated by volcanic fires. The rivers proceeding from the springs often resemble milk in appearance, owing to the argillaceous bole which they take up in their passage among the siliceous concretions: such are the white rivers of Olassai. Mount Hecla, like all the mountains of Iceland, is entirely covered with snow, and no smoke appears on its summit. Accumulations of rolled masses of obsidian and pumice-stone form a layer on the flanks of the mountain, thirty feet thick; stems and branches of the birch-tree occur in the midst of this bed ; they are the remains of the ancient forests of the island, which the volcanic eruptions have entirely extirpated.*

49. Siliceous thermal waters of New Zealand.—The phenomena under review are being effected at the present moment, on a much grander scale, in the volcanic districts of New Zealand. The principal volcanic mountain of that country is Tongariro, which has an elevation of 6200 feet above the level of the sea. Its crater is a quarter of a mile in diameter, and very deep; the sides are precipitous, and in some places overhanging, and the entire area is always covered with steam. From this crater streams and torrents of boiling water and vapour, highly charged with silex, are constantly issuing forth, and, flowing down the flanks of the mountain in cascades and torrents, empty themselves into lakes near its base, and deposit in their course siliceous sinter in great abundance, incrusting leaves, branches, and other extraneous substances. The whole of the surrounding

* Bulletin de la Société Géologique de France.

country for several miles, is studded with lakes and pools, and fountains of hot and boiling water ; and groups of mud ponds, or stufas, occur in considerable numbers. Some of the boiling torrents of the mountain find their way to the delta of the river Waikato, and cover a space of two miles square with an assemblage of thermal springs. The surface of this area appears to be only a thin crust of pumice and a friable sulphureous earth, with chalcedonic and siliceous incrustations, spread over volcanic caverns.

The most stupendous of these boiling pools is partly surrounded by a cliff sixty feet high, which is oxidized, corroded, and undermined from the effects of the heated vapours, which are continually issuing forth in jets. At the base of this cliff the pond is constantly boiling with a white foam, and throwing up fountains eight or ten feet high, with great noise and violence. Silex is thrown down by the boiling waters in the state of stalagmitic concretions, and this deposit resembles in colour and solidity the flint of the English chalk. This generally insoluble mineral is here held in solution by the alkaline elements and very high temperature of the water.

" Another and still more striking example of a thermal lake," observes Dr. Dieffenbach, from whose interesting work on New Zealand the preceding notice is taken, " is that of Rotu-Mahanu. Imagine a deep lake of a blue colour surrounded by verdant hills, and in this lake several islets, some showing the bare rocks, while others are covered with shrubs ; while on all of them steam issues from a hundred openings between the green foliage without impairing its freshness. On the opposite side is a flight of broad steps of the colour and aspect of white marble with a rosy tint from siliceous incrustations, over which flowed a cascade of boiling water into the lake. A part of this lake is separated from the rest by a ledge of rocks, forming

H 2

a lagoon in a state of ebullition, which discharges its waters into the Rotu-Mahanu."*

These modern siliceous formations are facts of great interest and importance; for they prove, in the clearest manner, that the most insoluble and refractory substance may be reduced to a liquid state, and again become consolidated, and assume numerous modifications, merely by the agency of thermal waters; hence the envelopment of the delicate corals, shells, &c. which are so abundant in chalk flints, is readily explained.

50. ARTIFICIAL SOLUTION OF SILEX.—The natural processes above described, have been successfully imitated in a series of experiments, conducted with great sagacity by Mr. Jeffery, with the view of determining whether silex is soluble in heated water, without the presence of alkalies, or other chemical agents. The following is a concise account of these important experiments.

A large boiler, used for vitrifying brown stone-ware, was heated by four exterior furnaces, each six feet long and five wide. Between each of these furnaces and the kiln a deep pit was made, and filled to a height of three feet with water, which was renewable from without. Some felspathic and siliceous minerals were placed in the direction of the current just within the kiln; and upon some of the arches a few earthenware vessels were placed, that any action upon them might be observed. Below a full red heat but little effect was perceived; but at a temperature above that of fused cast-iron, a rapid solution of mineral matter took place; this heat was continued for ten hours. When the kiln was opened, more than a hundred-weight of mineral matter had been dissolved and carried away in the vapour. The wall was eaten away, and presented a corroded and unglazed surface, like loaf-sugar partially

* Dr. Dieffenbach's New Zealand.

melted by water: and there was no appearance of the smooth glazed surface, which invariably attends the action of an alkali on a siliceous substance. Some of the earthenware vessels were partially eaten through; but on the uppermost arch, where the heat was only a full red, a curious phenomenon appeared; the articles there had received, exterior to their own glazing, and loosely incrusting it, a complete frosted siliceous coating, having the appearance of a candied surface. This was evidently a precipitation from the vapour; in fact, a hoar-frost of silex. There was from half an ounce to an ounce on each vessel, and altogether several pounds were thus precipitated; but by far the greater part of the vapourized mineral was, as might be expected, carried away by the current, and dissipated in the air. This powerful action was apparently entirely due to the presence of water; there being at all times the same quantity of alkali present in the fuel, whatever that might have amounted to, without producing such an effect. The experiment is conclusive as to the solvent power of water at a very high temperature on silica, and siliceous rocks; for the action cannot be attributable to the alkalies, because, under precisely similar conditions, the experiment failed when there was no water; and besides, each pound of alkali would have had to dissolve forty pounds of silica. Mr. Jeffery has in fact performed, on a small scale, the same operation which is incessantly going on in the volcanic regions of Iceland and New Zealand, and established the potency of heated water and vapour to effect the solution of silex.*

51. HERTFORDSHIRE PUDDING-STONE.—We have before us numerous examples of conglomerates formed by carbonate of lime; in other words, aggregations of pebbles,

* See an account of Mr. Jeffery's experiments in Reports of the British Association of Science, for 1840.

sand, shells, and corals, cemented together by calcareous spar; and others by ferruginous infiltrations: but this specimen is a congeries of rounded flint pebbles, imbedded in a siliceous paste. This conglomerate is commonly called Hertfordshire pudding-stone, and was formerly in much request with lapidaries; for the cement being as hard and solid as the pebbles themselves, the stone admits of being cut and polished into a great variety of ornaments. The formation of this rock must have resulted from a stream of siliceous matter having flowed through a bed of gravel, and cemented the pebbles into a solid mass, while those portions which the liquid flint did not reach, remained as loose water-worn materials.

But there are many very hard sandstones composed entirely of siliceous granules, which appear to have been formed simply by the effect of great pressure, there being no cementing medium; the rock, when broken, appearing like the fractured surfaces of fine sugar.*

It is not my intention in this lecture to dwell on the silicification † of the remains of animals and plants; it will

* A consolidation of this kind can be produced artificially. In the experiments made for the trial of the strength of gunpowder, leathern bags filled with sand are put into the mortar which is to receive the cannon ball, propelled by the powder from another gun at the distance of only fifty feet. The sand is frequently compressed by the percussion of the ball, into a mass of sandstone, sufficiently firm to remain solid and bear handling; and this sandstone is perfectly free from any cement. The consolidating power of great pressure has lately been ingeniously applied to various purposes; among others, to the formation of tesseræ from porcelain earth, and of graphite or plumbago, fit for the finest pencils, from the rubble of rejected ore formerly thrown by as useless. This rubble is reduced to an impalpable powder, and then subjected to great pressure in moulds, and the most pure graphite is the result: this prepared mineral is now generally employed for the best lead pencils.

† Petrifaction by flint.

suffice to remark, that in silicified wood the most minute vegetable structure may often be detected, although the specimens will strike fire with steel; and that the most delicate and perishable animal tissues are often preserved in flint.

52. Effects of high temperature.—The phenomena presented to our notice in this investigation of the Geysers of Iceland, and other natural solutions of silex in thermal waters, lead to the consideration of another agent in the transmutations that take place in the crust of the globe. It must be obvious to every intelligent mind, that beds of loose and porous materials can have acquired hardness and solidity only by one of the following processes; namely, either by matter dissolved in a fluid, and afterwards deposited among the porous masses in the manner just described; or by the reduction of the materials by heat into a state of softness or fusion, and their subsequent conversion, by cooling, into a solid mass.* Fire, or to speak more correctly, a high temperature, however induced—whether by electro-magnetic influence, or by central or medial sources of heat—and water, are therefore the chief agents by which the mineral masses composing the crust of our planet have been and are still being modified. We have already seen how vast are the changes which result from the effects of water; we must now take a rapid survey of the influence which caloric is capable of exerting; an influence far more universal and varied than we may at first be prepared to expect.

The expansive power which heat exerts on most substances, and its conversion of the most solid and durable bodies, first into a fluid, and lastly into a gaseous state, are phenomena so familiar as to require no lengthened comment. But the effects of heat are found to vary according to the circumstances under which bodies are submitted to its influence; hence the changes induced by high temperature

* Playfair.

beneath great pressure, are totally different from those effected by fire on the surface, under the ordinary weight of the atmosphere. A familiar example will serve to illustrate my meaning. Chalk consists of lime combined with carbonic acid; and as, for agricultural and other economical purposes, it is desirable to have the lime in its pure state, the chalk, or limestone, is exposed to a great heat, in kilns erected in the open air, until all the carbonic acid gas is dissipated, and the stone is said to be burnt into quicklime. In the specimens before us the same substance is seen in the state both of chalk and lime. It may readily be conceived, that if this operation were conducted beneath such a degree of pressure as would prevent the escape of the gaseous elements, the formation of quicklime would not take place; the chalk would be fused, and the carbonic acid, released from its present relation with the calcareous particles, would enter into other combinations, and the mass when cooled, be wholly different from the product of the lime-kilns, formed by the same agency in the open air. Experiments have proved that this opinion is correct. Sir James Hall exposed pounded chalk to intense heat, under great pressure, and it was fused, not into lime, but into crystalline marble: even the shells inclosed in the chalk underwent the same transmutation, yet preserved their forms.* That analogous changes have been effected by natural operations we have abundant proof; but in this stage of our inquiry it is only necessary to remark, that where ancient streams of lava have traversed chalk, the latter invariably possesses a crystalline structure. We shall hereafter find, in accordance with the philosophical theory of Dr. Hutton, that all the ancient

* From a table drawn up with due caution by Sir James Hall, it is proved that under a depth of the sea, not exceeding one-third of a mile, chalk would be converted into a crystalline limestone, and that at a depth of little more than a mile it would be in a state of fusion, provided there were no refrigerating causes in action.

strata have been more or less modified by heat, acting under great pressure and at various depths; and that the present position and direction of the rocks composing the crust of the globe, have been produced by the same cause.* The Huttonian theory, indeed, offers a satisfactory explanation of a great proportion of geological phenomena, and enables us to solve many of the most difficult problems in the science; and it is but an act of justice to the memory of its illustrious founder, and of his able illustrator, Professor Playfair, to state that this theory, corrected and elucidated by the light which modern discoveries have shed upon the physical history of our planet, is that embraced by the most distinguished modern geologists.

53. Volcanic agency.—Of the activity and power of the agent to which these remarks more immediately refer, the currents of melted rocks, called lavas, ejected through crevices and fissures of the earth, accompanied with evolutions of heat and vapour, afford the most striking proofs; and the volcano, with its frequent concomitant the earthquake, have in all ages excited the terror and astonishment of mankind. It would be foreign to the design of this discourse, to dwell upon the nature and causes of volcanic action. Dr. Daubeny,† Mr. Scrope,‡ and others, have published highly interesting treatises on the subject; and Mr. Lyell has given an admirable sketch of volcanic phenomena.§ I will only advert to the increased temperature of the earth in proportion as we descend from the surface towards the interior, and the profound depths from which thermal waters take their rise, as tending to support the opinion, that volcanic eruptions are occasioned by causes

* See Playfair's Illustrations of the Huttonian Theory, vol. i. p. 33, *et seq.* Edin. 1822.

† Daubeny's Lectures on Volcanoes, 1826.

‡ Scrope's Considerations on Volcanoes, 1825.

§ Principles of Geology, vol. ii.

which are constantly in action in the interior of the globe. We shall hereafter have occasion to demonstrate that dislocations of the strata, and elevations of the bottom of the ocean, and subsidences of the land, and eruptions of melted mineral matter, have taken place from the earliest periods within the scope of geological inquiries.

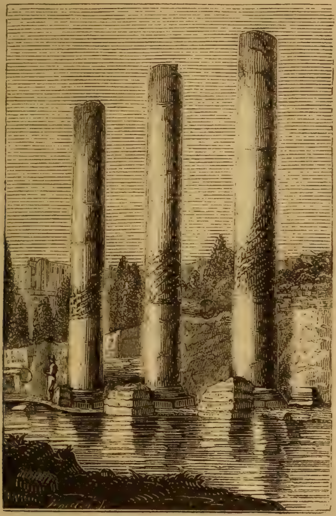
The expansive power of caloric, even in ordinary circumstances, is very considerable, as is shown by the instrument called a *pyrometer*, which illustrates a fact continually presented to our notice, namely, the expansion of a bar of metal by heat, and its contraction, by cooling, into its original dimensions. The expansion of solid bodies by heat, when effected on a large scale, gives rise to many interesting phenomena. The careful experiments made by Colonel Totten, on the expansion of granite, marble, and other rocks, by variations of temperature, have shown that the mere expansion, or contraction, of extensive beds of these materials, will account for the elevation and subsidence of considerable tracts of country, and explain many analogous phenomena.*

54. Subsidence and elevation of the temple of Jupiter at Puzzuoli.—One of the most interesting examples of local elevation and subsidence, apparently resulting from this cause, is that afforded by the remains of the celebrated temple of Jupiter Serapis, at Puzzuoli.

These ruins are situated on the northern shore of the Bay of Baiæ, at no great distance from the Solfatara, and consist of the remains of a large building of a quadrangular form, seventy feet in diameter; the roof of which was supported by twenty-four granite columns, and twenty-two of marble, each formed of a single stone. Many of the pillars are broken and their fragments strewed about the pavement, but three remain standing, and on them are

* American Journal of Science, vol. xxii.

inscriptions, not traced by the Greeks or Romans, but by some of the simplest forms of animal existence, which have here left enduring records of the physical changes that have



LIGN. 14.—REMAINS OF THE TEMPLE OF JUPITER SERAPIS, AT PUZZUOLI
(From Mr. Lyell's Principles of Geology.)

taken place on these shores, since man erected the temple in honour of his imaginary gods. The surface of the columns, the tallest of which is forty-two feet in height, is smooth and uninjured to an elevation of about twelve feet from the pedestal, where a band of perforations, nine feet wide, made by marine boring mussels *(modiola lithophaga)*, commences; and above this, that is, at the height of twenty-one feet from the pedestal, these cavities disappear. The hollows, many of which still contain shells, sand, and microscopic shields, are of an elongated elliptical shape, and are so numerous and deep, as to prove unquestionably that the pillars were submerged in sea-water, the base and lower portions having been protected from the depredations of the boring shells by accumulations of rubbish and tufa; while the upper parts projected above the waters, and consequently were beyond the reach of the *lithodomi.** The platform of the temple is now about one foot below high-water mark; and the sea, which is only forty yards distant, penetrates the intervening soil. The upper part of the band of perforations is now at least twenty-three feet above the level of the sea; and yet it is evident that the columns were once immersed in salt water for a long period. It is equally clear that they have since been elevated to their present height, and yet have maintained their erect position, amid the extraordinary changes to which they were subjected; thus incontrovertibly proving, that the relative level of the land and sea, on that part of the Mediterranean coast, has changed more than once since the Christian era; each movement, both of subsidence and elevation, having exceeded twenty feet.† And there, at the present moment—

"Those lonely columns stand sublime,
Flinging their shadows from on high,
Like dials, which the wizard Time
Had raised to count his ages by!"—Moore.

55. Historical evidence. — Fortunately, historical evidence throws some light on the respective dates of the most considerable changes of level, that the area on which the temple is situated has undergone. From inscriptions recording the embellishment of the temple by Septimus Severus and Marcus Aurelius, we learn that the building was entire, and occupied its original position, in the third century. In 1198 the eruption of the volcanic lake of the Solfatara took

* *Lithodomi,* from *lithos,* stone, and *demo,* to build.

† For a full account of the phenomcna, see Principles of Geology, vol. ii. p. 268.

place, and was accompanied by earthquakes ; a subsidence of the coast followed, and sunk the temple to a depth that submerged the columns in water to a height above the band of perforations. This state of things must have continued till the beginning of the sixteenth century ; for the flat district called La Starza, on which the temple stands, is described by contemporary observers as being covered by the sea in 1530. Eight years afterwards earthquakes were very frequent and violent along that part of the Neapolitan coast, and on the 29th of September a volcanic eruption suddenly burst forth, and threw up, in a single night, a mound of pumice and ashes 450 feet high, and a mile and a half in circumference ; and which still remains, and is called Monte Nuovo. During this catastrophe the coast on the north of the Bay of Baiæ was permanently elevated to the height of twenty feet, and formed a tract 600 feet in breadth, including the area occupied by the ruins of the temple, which were also elevated above the reach of the water, several of the columns retaining their original position.* These interesting relics of antiquity appear to have been wholly neglected till 1750, when the shrubs and weeds with which they were overgrown and concealed were removed, and the earth accumulated in the court of the temple cleared away. For the last thirty or forty years a slow subsidence of this coast appears to have been going on, and the floor of the temple is now often under water.†

56. Causes of these changes.—Professor Babbage attributes the tranquil elevation and depression of the temple, to the contraction and expansion of the strata on which it was built ; the sources of volcanic action in the sur-

* Professor James Forbes of Edinburgh, on the historical evidence relating to the elevations and subsidences of the Temple of Jupiter at Puzzuoli, and of the adjacent coast.—*Brewster's Edinburgh Journal of Science*, vol. i. *second series*.

† See a letter addressed to the author by Mr. Hullmandel, Appendix, F.

rounding country being very numerous, and a hot spring still existing on the land-side of the ruins. The change of level is therefore easily accounted for, by supposing the temple to have been built on the surface, when the rocks beneath were expanded by the effects of a high temperature, and that they subsequently contracted by slow refrigeration. When this contraction had reached a certain point, if a fresh accession of heat from the neighbouring volcano took place and increased the temperature of the strata, they would again expand, and thus raise the ruins to their present level.

Mr. Babbage carries out these views to explain the elevation of continents and mountain ranges, assuming the following facts as the basis of his theory :—

1st. As we descend below the surface of the earth, the temperature increases.

2dly. Solid rocks expand by being heated, but clay and some other substances contract.

3dly. Rocks and strata of dissimilar characters present a corresponding difference as conductors of caloric.

4thly. The radiation of heat from the earth varies in different parts of its surface ; according as it is covered by forests, mountains, deserts, or water.

5thly. Existing atmospheric agents, and other causes, are constantly changing the condition of the surface of the globe.

Thus wherever a sea or lake is filled up by the wearing down of the adjacent lands, new beds are formed, conducting heat much less quickly than the water ; while the radiation from the surface of the new land will also be different. Hence, any source of caloric, whether partial or central, which previously existed below that sea, must increase the temperature of the strata underneath to a much higher degree than before, because they are now protected by a bad conductor ;* and their expansion must therefore

* Sir John Herschel observes, that this process is precisely similar to that by which a great coat, in a wintry day, increases the feeling of

elevate the newly-formed deposits above their former level; —thus the bottom of an ocean may become a continent. The whole expansion, however, resulting from the altered circumstances, may not take place until *long* after the filling up of the sea ; in which case its conversion into dry land will result partly from the accumulation of detritus, and partly from the elevation of the bottom. As the heat now penetrates the newly-formed strata, a different action may be induced, the beds of clay or sand may become consolidated, and instead of expanding, may contract. In this case, either large depressions will occur within the limits of the new continent, or after another interval, the new land may again subside, and form a shallow sea. This sea may be again filled up by a repetition of the same processes as before; —and thus alternations of marine and fresh-water deposits may occur, having interposed between them the productions of the dry land.*

To review the physical changes which have taken place around the Bay of Naples would prove highly interesting, but my limits will only permit me to observe, that whole mountains have been elevated on the one hand, and temples and palaces submerged beneath the sea on the other. In our sister island we have evidence of former changes of a like nature, and which are alluded to by our inimitable lyric poet, in the following beautiful lines:—

> "On Lough Neagh's banks as the fisherman strays,
> When the clear cold eve's declining,
> He sees the round towers of other days
> In the wave beneath him shining !

---

warmth : the flow of heat outwards being obstructed, and the surface of congelation removed to a distance from the body by the heat thereby accumulated beneath the new covering.

* Proceedings of the Geological Society, March 1834.

"Thus shall memory often, in dreams sublime,
Catch a glimpse of the days that are over;
Thus, sighing, look through the waves of time
For the long faded glories they cover!"—Moore.

57. Elevation of the coast of Chili.—One of the most remarkable modern instances of the upheaval of an extensive tract of country, is that recorded by the late Lady Calcott, (then Mrs. Maria Graham,) as having been produced by the memorable earthquake which visited Chili in 1822, and continued at short intervals till the end of 1823. The shocks were felt through a space of 1,200 miles, from north to south. At Valparaiso, on the morning of the 20th of November, it appeared that the whole line of coast had been raised above its level; an old wreck of a ship, which could not previously be approached, was now accessible from the land; and beds of oysters, not before known in that locality, were brought to light. "When I went to examine the coast," says Lady Calcott, "although it was high-water, I found the ancient bed of the sea laid bare and dry, with oysters, mussels, and other shells, adhering to the rocks on which they grew: the fish being all dead, and exhaling the most offensive effluvia. It appeared to me, that there was every reason to believe the coast had been raised by earthquakes at former periods, in a similar manner; for there were several layers of beach, consisting of shingle mixed with shells, extending in parallel lines to the shore, to the height of fifty feet above the sea."* Part of the coast thus elevated consists of granite; subsequent observations have proved that the whole of the country was raised, from the foot of the Andes to far out at sea; the supposed area over which the elevatory movements extended, being about 100,000 square miles; a space

* Geological Transactions, vol. i. second series.

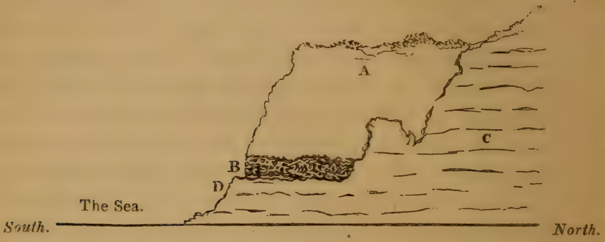
equal in extent to half the kingdom of France. Mrs. Somerville mentions, that a further elevation to a considerable extent has also taken place along the Chilian coast, in consequence of the violent earthquake of 1835.

58. Raised sea beach at Brighton.*—Examples of such changes occur in almost every part of the world, and there is perhaps no considerable extent of country, which does not afford some proof, that similar physical mutations have taken place in modern times. And although we have not a temple of Serapis on our shores, yet the cliffs from Brighton to Rottingdean afford unquestionable evidence that the relative level of land and sea, has undergone great changes within, to speak geologically, a comparatively recent period. The cliffs along the coast, from New Shoreham to Rottingdean, are composed of layers of chalk rubble, with flints slightly rolled, and interspersions of clay and loam; the whole being an accumulation of water-worn materials, deposited at some very remote period in an estuary or bay of the sea. The base of the cliffs, to the height of a few feet, consists of the chalk strata, which may be seen at low water extending far out to sea, being covered here and there by shingle and sand. Between the chalk and the superincumbent mass above described, is a bed of rolled chalk-flints, pebbles, and sand, with boulders of granite, porphyry, and other rocks, foreign to the south-east of England; in fact, a sea beach, formed in the same manner as the present bed of shingle which skirts the base of the cliffs. Among the pebbles of this ancient beach, are rolled masses of chalk and limestone, full of perforations made by boring shells; here are several specimens, with cavities

* The geological character of the cliffs at Brighton, and the occurrence of bones of elephants and other mammalia in those beds, were first described in my "Fossils of the South Downs," 1822.

similar to those made in the chalk-rock by the recent *pholades* and *mytili*.

These strata, which must have been deposited beneath the waves, now constitute a line of lofty cliffs, extending for miles along the sea-coast. The annexed diagram (*Lign.* 15)



Lign. 15.—Elevated strata and beach at Brighton, east of Kemp Town.

A, Elephant bed; B, Ancient bed of shingle; C, the Chalk; D, Terrace of Chalk beneath the ancient sea-beach.

represents a vertical section, as seen in those places where the inroads of the sea have extended to the chalk strata, and the face of the ancient cliff is exposed, the newer deposits being shown in profile from south to north; these consist of the following:—

1. (A), Chalk rubble, loam, &c., obscurely stratified; this deposit, from its containing many teeth and bones of elephants, I have named the Elephant bed; it constitutes the upper three-fourths of the cliffs.
2. (B), Shingle, or sea beach and sand, several feet above high-water mark. This ancient shingle, which from the inroads of the sea extends in the cliffs beyond Kemp Town but a short distance inland, is constantly found beneath the loam and clay, several hundred yards north of the shore, in the western part of Brighton. In wells sunk in the Western road, the shingle bed was reached at the depth of fifty-four feet.

3. (c), The undisturbed chalk, which forms a sloping cliff, inland, behind the elephant bed (A) and shingle (B), passes under the latter, and appears as a terrace at the foot of the present cliffs (D).*

These appearances demonstrate the following sequence of changes in the relative level of the land and sea on the Sussex shores :—

First. The chalk terrace on which the ancient shingle rests, was on a level with the sea for a long period; and the beach was formed, like the modern shingle, by the action of the waves on the then existing chalk cliffs. The rolled condition of the materials, and the borings of the *lithodomi*, prove a change of level as decidedly as do the bands of perforations in the columns of the temple of Jupiter at Puzzuoli.

Secondly. The whole line of coast, with the shingle (B), was submerged to such a depth, as to admit of the deposition of the uppermost strata (A).

Lastly. The cliffs were raised to their present elevation, and at this period the formation of the existing sea beach commenced.

Here, then, we have unquestionable evidence that the Sussex shores have been subjected to changes similar to those produced by earthquakes on the Chilian coast.

A phenomenon of a like nature, but of a far more ancient period, is observable at Castle Hill, near Newhaven, about eight miles east of Brighton; there, immediately beneath the turf, is a regular sea beach with oyster-shells, many feet in thickness, forming the summit of the chalk cliffs, 150 feet above the level of the sea.

Near Bromley in Kent, and Reading in Berkshire, similar accumulations of pebbles and oyster-shells are to be found. Elevated beds of shingle, of comparatively recent

* See Geology of the South-East of England, p. 30; Fossils of the South Downs, p. 277; Medals of Creation, vol. ii. p. 913.

epochs, occur likewise on the shores of the Frith of Forth, and along the eastern and western coasts of England.

59. Elevation of Scandinavia.—Having thus adduced a few striking proofs of the mutations which the land has undergone in past times, we are led to inquire—is this change still going on? is the alternate subsidence and elevation of the land the effect of a law of nature, established from the commencement of the present condition of our planet, and destined to continue in action while its physical constitution remains the same? We may unhesitatingly reply in the affirmative, for there are innumerable proofs that this law has been in constant action from the earliest periods; and I now proceed to adduce an instance in which the elevation of a whole country is actually taking place, unsuspected by the busy multitude which inhabit its towns and cities, and known only by the researches of the natural philosopher. I allude to Scandinavia, which is slowly and visibly rising, from Frederickshall, in Sweden, to Abo, in Finland, and even, perhaps, as far as St. Petersburgh; while the adjacent coast of Greenland is suffering a gradual depression. The state, therefore, is one of oscillation, the waters appearing to sink at Torneo, and to retain their former level at Copenhagen.

The opinion that Sweden is in this state of change, is no new idea; it was long since entertained by Celsius, and other Swedish philosophers.* Mr. Lyell, who has twice

* Celsius remarks, "that several rocks on the shores of the Baltic, which are now above the water (A.D. 1730), were, not long before, sunken rocks, and dangerous to navigators; one especially, which, in the year 1680, was on a level with the surface of the water, is twenty and a half Swedish metres above it. From an inscription, near Aspô, in the Lake Melar, which communicates with the Baltic, engraved, as is supposed, above 500 years ago, the land appears to have risen no less than thirteen Swedish feet."—*Playfair's Illustrations of the Huttonian Theory,* p. 436, edit. 1822.

visited Scandinavia within the last few years, with the view of determining this interesting question, expresses himself fully convinced that certain parts of Sweden are undergoing a gradual rise, to the amount of two or three feet in a century ; while other tracts, farther to the south, appear to have experienced no movement.* He surveyed the shores of the Bothnian Gulf, between Stockholm and Gefle, and on the western coasts of Sweden, districts particularly alluded to by Celsius. Upon examining the marks cut by the pilots, under the direction of the Swedish Academy of Sciences, in 1820, the level of the Baltic, in calm weather, was found to be several inches lower than the marks, and from two to three feet below those made seventy or a hundred years ago. Similar results were obtained on the side of the ocean, and in both districts the testimony of the inhabitants agreed with that of their ancestors, as recorded by Celsius. On the shores of the Northern Sea, there are banks of recent shells, at various heights, from 10 to 200 feet ; and on the side of the Bothnian Gulf, between Stockholm and Gefle, there are deposits containing fossil shells of the species which now inhabit the brackish waters of that sea. These occur at different elevations, from one to a hundred feet, and sometimes extend fifty miles inland. Some of the shells are marine, and others fluviatile ; the marine species are identical with those now living in the ocean, but are small in size, and never attain the average dimensions of those which live in water sufficiently salt to enable them to reach their full development. The specimens before us were collected by Mr. Lyell at Uddevalla, in Sweden, from the summit of cliffs twenty feet above the level of the sea ; they consist of marine species, which still inhabit the neighbouring waters.

* Philosophical Transactions. Principles of Geology, Fifth Edition, vol. ii. p. 286.

60. Mutations in the relative level of land and sea.—Of the reality of these changes in the relative level of the land and of the Northern Ocean, there cannot exist a doubt; but the mind is so accustomed to associate the idea of stability with the land, and of mutability with the sea, that it may be necessary to offer a few additional remarks on these highly interesting facts. As it is the property of all fluids to find their own level, it is obvious that if the level of the sea be elevated or depressed in any one part, that elevation or depression must influence the whole surface of the ocean, and the level therefore cannot be affected by local causes. But movements of the land may take place, and the effect extend over whole countries, as in South America,—or along lines of coast, as in Sussex, —or be confined to a single island,—or even to the area of a temple, as at Puzzuoli.*

But while the land is rising in the more northern latitudes, it appears to be sinking on the shores of the Mediterranean. Breislak mentions † that numerous remains of buildings are to be seen in the Gulf of Baiæ; ten columns of granite, at the foot of Monte Nuovo, are nearly covered by the sea, as are the ruins of a palace built by Tiberius in the island of Caprea. Thus while the level of the sea is becoming lower in the north, from the elevation of the land, it is *rising* in the Mediterranean, from the sinking of its coasts. Now, as all the parts of the ocean communicate, the water cannot permanently rise in one part and sink in another, but must rise and fall equally to maintain its level; we must therefore consider it as demonstrated, that these changes are solely dependent on the elevation and depression of the land. If we bear in mind the insignificance of the masses affected by these operations,

* See Playfair's admirable commentary on this geological problem, "Illustrations," p. 433.

† Playfair.

as contrasted with the earth itself (*see page* 35), we may readily conceive that as fissures and inequalities are produced in the varnish of an artificial globe by heat and cold, in like manner the elevation of mountain chains, and the subsidence of whole continents, may be occasioned by the expansion or contraction of portions of the earth's crust, from sudden changes in the internal temperature of the globe.

61. RETROSPECT.—In this rapid sketch of the geological phenomena, which an examination of the surface of the earth presents to our notice, I have doubtless dwelt on several subjects familiar to many of my readers. But, as one of our ablest geologists* has remarked, "the teacher of Geology must suppose himself called on to answer questions, both concerning the facts of the science, and the inferences to be deduced therefrom; and his instructions will be so much the more successful as he takes these questions in the most natural order of their occurrence, and answers them most completely and satisfactorily. In doing this he is not at liberty to neglect even elementary truths, for if these were passed over in compliment to such as have made progress in the science, those for whose advantage he is especially interested, would be called to the unreasonable task of labouring without instruments, and of theorizing without intelligible data."

From the vast field of inquiry over which our observations have extended, it may be useful to offer a brief summary of the leading principles that have been enunciated, and the facts on which they are founded. By the most profound investigations of which the human mind is capable, we learn that our earth is one of myriads of spherical bodies, revolving round certain luminaries; and that these bodies occur in every variety of condition, from that of a diffuse

* Professor John Phillips.

luminous vapour, to opaque solid globes like our own. All the materials of which the earth is composed may exist either in a solid, fluid, or gaseous state ; and simply by a change of temperature, or by electro-chemical agency, every substance may undergo a transition from one state to the other. Water existing as ice, fluid, or vapour, and separable into two invisible gases, offers a familiar example of a body constantly exhibiting these transmutations; and mercury, of a metal which, though generally in a fluid state, becomes, when exposed to a very low temperature, a solid mass like silver. The relative position of land and water, and the inequalities on the surface of the earth, are subject to constant changes, which are regulated by certain fixed laws. The principal causes of the degradation of the land are atmospheric agencies, variations of temperature, the action of running water, and of icebergs, glaciers, &c., by which the disintegrated materials of the land are transported into the bed of the ocean. The mud, sand, and other detritus thus produced, are consolidated by certain chemical changes which are in constant activity, both on the land and in the depths of the ocean, and new rocks are thus in the progress of formation. But the conjoint effect of these operations is unremitting destruction of the surface of the land; and were there no conservative process, the whole of the dry land would disappear, and the earth be covered by one vast sheet of water. The globe, however, possesses an internal source of heat, and whether this exists as a central nucleus of high temperature, or as medial foci, — whether it be dependent on the assumed original nebulous state of the earth, or produced by chemical or electro-magnetic forces acting on the mineral substances contained in the interior of our planet,—does not affect the present inquiry. This internal heat, however induced, must occasion constant changes in the relative level of the land and water;

elevating and depressing whole continents,—converting the bed of the sea into dry land,—and submerging the dry land into the abyss of the ocean. The volcano and the earthquake are the effects of its local and paroxysmal energies,—the quiet and insensible elevation and subsidence of the land, of its slow but certain operation. By this antagonist power the accumulation of the spoils of the land, which the rivers, waves, and currents have carried into the bed of the ocean, are again brought to the surface, and form the elements of new islands and continents; and by the organic remains discovered in the strata, we trace the nature of the countries whence these spoils were derived. In the deltas and estuaries of modern times,—in the detritus accumulating in the beds of the ocean,—in the recent tracts of limestone forming on the sea-shores,—beneath the cooled lava currents erupted from existing volcanoes,—the remains of man and of his works, and of the animals and plants which are his contemporaries, are found imbedded.

The dynamical effects of elevation appear to be referable to three great divisions:—1. The gradual rising of ridges through large spaces of the earth's crust, and the consequent production of longitudinal fissures and lines of volcanic vent; 2. The long-continued protrusion and eruption of igneous rocks along such lines of vent; and 3. Local eruptions and protrusions, producing valleys of elevation, dislocations of the strata, and other phenomena that terminate in ordinary volcanic action.

Such are the deductions derived from the phenomena which have been submitted to our examination. To the mind previously unacquainted with the elements of geology, I am ready to acknowledge that to attribute mutability to the rocks and the mountains, must appear as startling and incredible, as did the astronomical doctrines of Galileo to the people of his times; but the intelligent reader, who has attentively considered the facts presented, even in this brief survey, cannot, I conceive, refuse assent to the inferences thus cautiously obtained. As we proceed in our investigations, we shall find that from the earliest period of the present physical condition of our planet, its surface has undergone repeated modifications in the relative distribution of the water and the land; and as the rocks and mountains and plains have been subjected to perpetual mutation, the element which has hitherto been considered as the type of mutability, can alone be regarded as having suffered no change. This idea is finely embodied by Lord Byron in the following sublime apostrophe to the Ocean, with which I will conclude this discourse.

"Thy shores are empires, changed in all save thee—
Assyria, Greece, Rome, Carthage, what are they?
Thy waters wasted them while they were free,
And many a tyrant since; their shores obey
The stranger, slave, or savage; their decay
Has dried up realms to deserts:—not so thou,
Unchangeable, save to thy wild waves' play—
Time writes no wrinkle on thine azure brow—
Such as Creation's dawn beheld, thou rollest now!"

Childe Harold, Canto iv.

LECTURE II.

1. Introductory. 2. Extinction of Animals. 3. Law of Extinction. 4. Animals extirpated by Human Agency. 5. Apteryx of New Zealand. 6. Moa of New Zealand. 7. Dodo of the Mauritius. 8. Irish Elk. 9. Epoch of Terrestrial Mammalia. 10. Fossil Mammalian Remains. 11. Comparative Anatomy. 12. Osteology of the Carnivora. 13. Osteology of the Herbivora. 14. Dental organs of the Rodentia. 15. General Inferences. 16. Fossil Elephants, &c. 17. Fossil Mammalia of the valley of the Thames. 18. Fossil Elephants of other parts of England. 19. Extinct Elephant or Mammoth in Ice. 20. Mammoths of the alluvial deposits of Russia. 21. Siberia and Russia in the Mammoth epoch. 22. Mastodon. 23. Mastodons of Ava. 24. Fossil Mammalia of the Sub-Himalayahs. 25. Sub-Himalayah tertiary deposits. 26. Remarkable collocation of Fossil animals. 27. The Pampas. 28. The Sloth tribe. 29. Megatherium. 30. Mylodon. 31. Megalonyx. 32. Glyptodon. 33. Toxodon. 34. Fossil Hippopotamus, &c. 35. Dinotherium. 36. Fossil Carnivora in Caverns. 37. Cave of Gaylenreuth. 38. Förstershöhle, or Forest-cave. 39. Bone Caverns in England. 40. Diseased Bones found in Caverns. 41. Human Bones in Caverns. 42. Osseous Breccia. 43. The Rock of Gibraltar. 44. Osseous Breccia of Australia. 45. Retrospect.

1. Introductory.—In the previous Lecture we took a comprehensive view of the actual physical condition of the surface of our planet, and of the nature and effects of the principal agents by which the land is disintegrated and renewed. We found in the modern fluviatile and marine deposits, that the remains of man, of works of art, and of existing species of animals and vegetables, were preserved. In every step of our progress, the grand law of nature, alternate decay and renovation, was exemplified in striking characters. Whether in the regions of eternal snow, or in torrid climes—in the rocks and mountains, or in the verdant plains—by the agency of heat, or by the effect of cold—of drought, or of moisture—of steam, or of vapour—by the abrasion of torrents and rivers—by inundations of the ocean—or by volcanic eruptions—still the work of destruc-

tion, in every varying character, was apparent. And on the other hand we perceived that amidst all these processes of decay and desolation, perpetual renovation was going on ; and that Nature was repairing her ruins, and accumulating fresh materials for new islands and continents, and that innumerable living instruments were employed to consolidate, and build up the rocky fabric of the earth ; and that even the most terrific of physical phenomena, the earthquake and the volcano, were but salutary provisions of the Supreme Cause, by which the harmony and integrity of our planet were maintained and perpetuated.

The occurrence of human skeletons in modern limestone —of coins and works of art in recent breccia—and the preservation of the bones of existing species of animals, and of the leaves and branches of vegetables, in the various deposits that are in progress of formation, incontestably prove that enduring memorials of the present state of animated nature will be transmitted to future ages. When the beds of the existing seas shall be elevated above the waters, and covered with woods and forests—when the deltas of our rivers shall be converted into fertile tracts, and become the sites of towns and cities—we cannot doubt that in the materials extracted for their edifices, the then existing races of mankind will discover indelible records of the physical history of our times, long after all traces of those stupendous works, upon which we vainly attempt to confer immortality, shall have disappeared.

But we must now proceed, and pass from the ephemeral productions of man, to the enduring monuments of nature—from the coins of brass and silver, to the imperishable medals on which the past events of the globe are inscribed—from the mouldering ruins of temples and palaces, to the examination of the mighty relics, which the ancient revolutions of the earth have entombed.

2. Extinction of animals.—Before we enter upon the geological history of the period immediately antecedent to the present, it will be necessary to notice one of the most remarkable facts which modern investigations have demonstrated, namely, the annihilation of numerous species and genera of animals and plants.

From the continual transmutations in the distribution of land and water, to which the earth's surface has been subjected, as indicated by our previous remarks, the destruction of some forms of animal life would seem to be a probable, if not inevitable, result ; and such proves to have been the case. But not only has the extinction of certain races taken place ; — a rigid examination of the fossil remains entombed in the various strata, demonstrates that other species, suited to peculiar states of the earth, have successively appeared, and played their part in the drama of life ; and when the physical conditions of the lands and waters were altered, so as to be no longer adapted for the continuance of those types of animated nature, they in turn passed away, and were succeeded by new forms of organization.

The annihilation of whole tribes of animals and plants has no doubt depended on a variety of causes ; and it is probable that in the earlier ages, an important agent in the extinction of many species, both terrestrial and aquatic, was the frequent oscillation in the relative position of the land and sea, and the consequent variations in atmospheric conditions.

3. Law of extinction.—But there is another consideration that bears upon this problem, and to which I must here briefly allude. It has been found that in countries where certain formations follow each other in tranquil and uninterrupted succession, the same restriction of particular fossils to special groups of strata, and the same disappearance of some species, and the first advent of others,

as rigidly prevail as in England, where the strata have been subjected to violent and repeated physical revolutions.

This is remarkably the case in Russia, where the Silurian, Devonian, Carboniferous, and Permian systems of rocks extend over immense regions, and are composed of horizontal deposits of different ages, nearly all conformable in position, and yet clearly separable from each other by mineral characters and organic remains. Here then is unequivocal proof, that some races of animals have disappeared and been succeeded by others, over enormously extended areas, in which there has never been any great physical catastrophe, nor the smallest eruption of plutonic or volcanic matter.*

These facts naturally suggest the inquiry, whether the continuance of species may not be governed by some natural law, in like manner as is the duration of the life of the individuals of any given species. May not some species, for example, be so constituted as to continue but for a few hundreds or thousands of years—others for ages—while other organisms may be endowed with a perpetuity of reproduction through all time? In this view of the subject, species may have become extinct, simply because the predestined term for the persistence of that peculiar form of organism was expired; and this may have taken place without any necessary relation to surrounding physical conditions. In fine, may not the termination of the race, like the death of the individuals, be the natural and inevitable result of their organization?

4. Animals extirpated by human agency.—But leaving for the present the further consideration of this

* "Geology of Russia," by Sir R. I. Murchison. These highly interesting results, which are entirely due to the labours of this eminent philosopher, have introduced a new and important element in all speculations relating to the cause of the extinction of species in the ancient geological periods.

difficult problem, we pass to the examination of the effects of human agency on the extinction of animals; and we shall find conclusive evidence, that since Man became the lord of the creation, his necessities and caprice have occasioned the extirpation of many species of animals, of which relics occur in the superficial alluvial deposits, associated with those of contemporary species, but concerning which both history and tradition are silent.

In this country, the beaver, wolf, hyena, bear, &c. are examples of animals which, though exterminated in these islands, still exist on the continent; while the Mammoth and Irish Elk, of which numerous remains are found in our alluvia and drift, have long since been obliterated from the face of the earth. That the gradual extinction of many of the existing species of animals will be effected by human agency alone, cannot admit of question. In those animals which supply fur, a remarkable proof of the immense destruction which is carried on, is stated in a late number of the American Journal of Science. "Immediately after South Georgia was explored by Captain Cook, in 1771, the Americans commenced carrying seal-skins from thence to China, where they obtained most exorbitant prices. *One million two hundred thousand skins* have been taken from that island alone, since that period; and nearly an equal number from the Island of Desolation! The numbers of the fur-seals killed in the South Shetland Isles (S. lat. 63°,) in 1821 and 1822, amounted to three hundred and twenty thousand. This valuable animal is now almost extinct in all these islands." From the most authentic statements it appears certain that the fur trade must henceforward decline, since the advanced state of geographical science shows that no new countries remain to be explored. In North America the animals are slowly decreasing from the persevering efforts, and the indiscriminate slaughter, practised by the hunters, and by the appropriation to the use of man, of those forests and rivers which once afforded them food and protection. They recede with the aborigines before the tide of civilization.

Before we proceed further in this argument, it will be interesting to notice a few of the links which connect the present "chain of being" with the past;—in other words, those species which are on the point of extinction, and others which have disappeared within a comparatively recent period.

5. THE APTERYX (*wingless bird*) OF NEW ZEALAND.—The Apteryx, a bird peculiar to New Zealand, and belonging to a very limited group, of which the Ostrich is a well-known type, appears to be rapidly approaching extinction. It is of the size of a small turkey, of a chestnut-brown colour, the feathers being long, lanceolate, and hair-like, as in the Emu, but each plume has but a single shaft. It has a slightly-curved bill, with the nasal apertures at the apex,

LIGN 16.—THE APTERYX OF NEW ZEALAND.

not at the base, as in birds with a similar conformation of beak, which is adapted for respiration while immersed in mud or water. It has no visible wings; and in the skeleton the bones of the arm are but very little developed. Its habits are nocturnal, and it feeds on worms and insects.

It is very difficult to be obtained, and is hunted by torch-light by the natives for the sake of its skin, which is highly prized to ornament the dresses of their chiefs. It has become very rare, and must soon be exterminated, for its numbers are fast diminishing.*

6. THE MOA (*Dinornis* of Professor Owen,) OF NEW ZEALAND.—About eight years since a portion of a femur (thigh-bone) of large size was brought from New Zealand, and submitted to the examination of Professor Owen, who pronounced it to belong to a gigantic bird of the same family as the Apteryx. Subsequent discoveries have proved the correctness of this inference, and the numerous bones since received, establish the former existence in the islands of New Zealand, at no very distant period, of a tridactyle bird, resembling the Apteryx in its general conformation, but one-third larger than the African Ostrich. These bones were found in the alluvial mud of the rivers; the largest collection sent to England was obtained by the Rev. W. Williams, from Poverty Bay; the bones are in a very fine state of preservation, and resemble those found in our recent fluviatile clays and silt.

It seems probable that these remains are washed out of an ancient alluvial deposit, that forms the present river-channels: for I am informed by my son (Mr. Walter Mantell, of Wellington, N. Z.) that he obtained bones from a potato-pit sunk by a native at some distance from any stream. If this be the case, these relics occupy the same relative geological position as those of the mammoth, horse, &c., that occur in the banks of the Thames.

It is remarkable that these bones were referred by the

* See Trans. Zoolog. Soc. of London, vol. ii. Another species of Apteryx has very recently been discovered in New Zealand; it is three feet high, and its eggs are as large as those of the Emu; it may possibly be a species of Moa.

natives to a gigantic bird, which they deemed sacred, and called Moa, before these relics had been examined by any European, and when the New Zealanders could not have known of the existence of a bird larger than their own Apteryx. The native traditions assert the former abundance of these birds, and the existence of the race at the present time, within the hallowed and not to be violated precincts of Tongariro. But though, from the state of the bones, it is probable that the Moa (if extinct) was exterminated, like the Irish Elk, and the Dodo, by man, yet no trustworthy evidence has been obtained to prove that it was ever contemporary with the present inhabitants.*

The bones hitherto sent to this country belong to numerous individuals, and are referable to seven or more species, materially differing from each other in size. A considerable portion of the cranium has been obtained, and this approximates very nearly to the skull of the Dodo.

Thus we have certain evidence that the Islands of New Zealand (which are situated between the 30th and 50th degrees of south latitude, and are about 900 miles in length) were inhabited, at no very remote period, by numerous species of struthious (*Ostrich-like*) birds, some of much greater magnitude than any now known to exist; that these are extinct, and but one solitary and diminutive type of this wingless race, the Apteryx, remains; and this, in all probability, is destined to be speedily exterminated.

7. The Dodo (*Didus ineptus*).—A remarkable instance of the extirpation of a very peculiar type of organization is afforded by the Dodo, which has been annihilated, and become a denizen of the fossil kingdom, almost before our eyes. The Dodo was a terrestrial bird of the struthious

* For a full account of the Moa, see Professor Owen's Memoir in the Zoological Transactions; also my Medals of Creation, vol. ii. p. 816.

family, larger than a turkey, of a dun colour on the back, and marked on the breast like a cock pheasant; it abounded in the Mauritius and adjacent islands. When those countries were first colonized by the Dutch, about two centuries ago, the Dodo formed the principal food of the inhabitants;

LIGN. 17.—THE DODO.

(From a Painting in the British Museum.)

but as it unfortunately proved to be incapable of domestication, its numbers were soon diminished, and the species insensibly disappeared. A live Dodo was exhibited in London in 1638 as a great curiosity; and stuffed specimens were preserved in the various museums of Europe: paintings of the living animal are still extant in the Ashmolean Museum at Oxford, and in the British Museum (see *Lign.* 17). But the Dodo is now extinct; it is no longer to be found in the isles where it once flourished, and even all the stuffed specimens are destroyed. The only known relics that remain, are the head and foot of an individual in the Ashmolean, the leg of another in the British Museum, and a skull in the museum at Copenhagen. To render this illustration complete, some bones of the Dodo have been found in a tufaceous deposit, beneath a bed of lava, in the Isle of France, and in a cave in the Isle of Rodriguez; so that if the figures and remains of the recent birds above mentioned had not been preserved, these fossils would have constituted the only proof that such creatures had ever existed.

Thus it appears that of the few genera comprised in the remarkable family of birds, to which the Ostrich and Cassowary belong, no less than two have become extinct; one, the Dodo, within the last century and a half; the other, the Moa, at no very remote period; while a third, the Apteryx, will soon share the same fate.*

We pass on to the consideration of the extinct mammalia.

8. THE IRISH ELK, (*Cervus megaceros*, or Elk with great antlers.) The shell marls of Ireland contain the bones of an animal which, like the Dodo, was once contemporary with the human species, but is now extinct: the last individuals of the race having, in all probability, been destroyed by man. These remains commonly occur in the beds of marl beneath the peat-bogs, which are apparently like those of Scotland, the sites of ancient lakes, and bays. In Curragh, immense quantities of these bones lie within a small space; the skeletons appear to be entire, and are found with the skull elevated, and the antlers thrown back on the shoulders, as if a small herd of these Elks had sought for refuge in the marshes, and had sunk into the morass and been suffocated. Remains of the Elk occur also in marl

* The Struthionidæ are remarkably restricted in their geographical distribution. Thus the Ostrich inhabits Africa, and the Rheus, America; while the Dodo appears to have been limited to the Mauritius, and the Moa and Apteryx confined to New Zealand. See a highly interesting article on the DODO in the Penny Cyclopedia.

and gravel, in many parts of England, France, Germany, and Italy, associated with recent species of river-shells.

This extinct creature far exceeded in magnitude any living species of deer. The skeleton is upwards of ten feet high from the ground to the highest point of the antlers, which are palmated, and are from ten to fourteen feet from one extremity to the other.* Skulls have been found without horns, and are supposed to have belonged to females; the average weight of the skull and antlers is about seventy-five pounds. The bones are generally in a fine state of preservation, of a dark brown colour, with here and there a bluish incrustation of phosphate of iron, like those of the deer from Lewes Levels. In some instances they are in such a state of preservation that the medullary cavities contain marrow having the appearance of fresh suet, and which burns on the application of a lighted taper. This Elk shed its horns, and probably, like existing species, annually. The researches and observations of Professor Jameson, Mr. Weaver, and others, have rendered it highly probable that this majestic creature was coeval with man. A skull was discovered in Germany, associated with urns and stone hatchets; and in the county of Cork, a human body was exhumed from a wet and marshy soil, beneath a bed of peat eleven feet thick; the body was in good preservation, and enveloped in a deer-skin covered with hair, which appeared to be that of a gigantic Elk. A rib of this animal has been found, in which there is a perforation evidently occasioned by a pointed instrument while the creature was alive; for there is an effusion of callus or new bony matter, which could only have resulted from something remaining in the wound for a considerable period; such an effect, indeed, as would be produced by the head of an arrow or spear.†

* There is a fine skeleton of the Irish Elk in the British Museum.

† Jameson's Cuvier.

There is, therefore, presumptive evidence that the last individuals of the race were extirpated by the hunter-tribes who first took possession of these islands.

Beds of gravel and sand, containing recent species of marine shells with bones of the Irish Elk, have been observed in the vicinity of Dublin, at an elevation of two hundred feet above the level of the sea.* This extinct quadruped, though found in peat-bogs and morasses of comparatively very recent date, must therefore have been an inhabitant of Ireland antecedently to some of the last changes in the relative position of the land and water. The discovery of a vast number of skeletons in the small area of the Isle of Man, seems to indicate a great alteration in the extent of land and sea; for it is difficult to conceive that such herds of this gigantic race could exist in so limited a district. It is therefore probable that the island was separated from the main land at no remote geological period, by subsidences commensurate with the elevations of which Ireland affords such decisive evidence.

In the examples above described, we have an interesting transition from the living to the lost types of animal existence. 1st, Species no longer inhabitants of the British islands, but still living in other countries; 2dly, Animals which have been exterminated within the last few centuries; lastly, Species that have been utterly destroyed by the early races of mankind.

9. Epoch of terrestrial mammalia.—We must now advance another step in the history of the past, and proceed to the consideration of the geological phenomena presented by the period immediately antecedent to the present, when vast regions were inhabited by large herbivorous mammalia, with which species of existing races were associated. Thus while the present may be termed the *Modern* or

* By Dr. Scouler.

Human Epoch, that which forms the immediate subject of investigation may be designated the *Epoch of terrestrial mammalia.*

"When the traveller," says Cuvier, "passes over those fertile plains, where the peaceful waters preserve, by their regular course, an abundant vegetation, and the soil of which is crowded by an extensive population, and enriched by flourishing cities, which are never disturbed but by the ravages of war, or the oppression of despotism, he is not inclined to believe that nature has also had her intestine wars, and that the surface of the globe has been overthrown by various revolutions and catastrophes. But his opinions change as he penetrates into that soil at present so peaceful; or as he ascends the hills which bound the plains. His ideas expand, as it were, with the prospect; and so soon as he ascends the more elevated chains, or follows the beds of those torrents which descend from their summits, he begins to comprehend the extent and grandeur of the physical events of ages long past. Or if he examines the quarries on the sides of the hills, or the cliffs which form the boundaries of the ocean, he there sees, in the displacement and contortion of the strata, and in the layers of water-worn materials, teeming with the remains of animals and plants, proofs that those tranquil plains, those smooth unbroken downs, have once been at the bottom of the deep, and have been lifted up from the bosom of the waters; and everywhere he will find evidence that the sea and the land have continually changed their place."*

In almost every part of the world, beneath the modern alluvial soil, extensive beds of gravel, clay, and loam, are found spread over the plains, or on the flanks of the mountain chains, or on the crests of ranges of low elevation; and in these accumulations of marine and fluviatile debris, are

* "Discours sur les Révolutions de la Surface du Globe."

imbedded immense quantities of the bones of large mammalia. These belong principally to animals related to the elephant, as the mammoth, mastodon, &c., and to species of hippopotamus, rhinoceros, horse, ox, deer, &c. ; and some are referable to extinct genera ; while in caverns and fissures of rocks, more or less filled with loam and breccia, bones of tigers, boars, hyenas, and other carnivora, occur. Fossils of this kind exist in great abundance in various parts of Europe, Asia, and America; they are found alike in the tropical regions of India, and in the frozen plains of Siberia; and there are but few considerable districts in Great Britain in which some vestiges of this kind do not occur.

10. Fossil mammalian remains.—For the convenience of study, Dr. Buckland classes these remains under five heads, namely:—

First. Bones of land animals, that were drifted into estuaries, and are associated with marine shells; such as those found in the Sub-Apennine formations; and in the beds of gravel, sand, &c. provincially termed *Crag*, in Norfolk and Suffolk ; in loam and chalk conglomerate in the cliffs of Kent and Sussex; and in clay off Harwich and Herne Bay.

Secondly. Terrestrial quadrupeds, imbedded with fresh-water shells, in strata that have been formed during the same epoch as the above, at the bottom of fresh-water lakes and in the beds of rivers and deltas; such are the fossil bones of the lacustrine marls of the Val d'Arno; those in the valley of the Thames, &c.

Thirdly. Similar remains in superficial drift spread over the surface of rocks of all ages ; as in beds of gravel near London; Petteridge Common in Surrey, &c.

Fourthly. Bones of carnivorous and herbivorous animals, accumulated in caverns and fissures of rocks, during the later period of the same epoch. The caves of Gaylenreuth, Kirkdale, Kent's Hole near Torquay, &c. are examples.

Lastly. Osseous breccias that occur in fissures of limestone on the shores of the Mediterranean, in the Ionian Isles, in the rock of Gibraltar, at Plymouth, in the Mendip hills, &c.*

Before directing your attention to the fossils before us, which are from alluvial deposits of various ages and from different localities, it will be necessary to review the leading principles of the science which treats of the structure of organized beings. Thus while in the preceding lecture we referred to Astronomy to dissipate the obscurity which shrouded the earliest physical condition of our planet, we are now led to that important department of natural knowledge termed *Comparative Anatomy*, to enable us to determine the extinct forms of animal existence. I shall therefore explain the mode of induction employed by the scientific observer in the investigation of the fossil remains of animals, and by which he is enabled to ascertain the structure and economy of creatures, which have long since disappeared from the face of the earth.

11. Comparative anatomy.—To a person uninstructed in anatomical details, the specimens before us would appear a confused medley of bones, and of osseous fragments impacted in solid stone; and the only knowledge he could derive from their examination would be the fact, that the stone was once in the state of sand or mud, in which, while soft, the bones had become imbedded. But in vain would he seek for further information from these precious historical monuments of Nature; to him they would prove as unintelligible as were the hieroglyphics of Egypt, before Young and Champollion explained their mysterious import. It is only by an acquaintance with the structure of the living

* Dr. Buckland's Bridgwater Essay, p. 94.

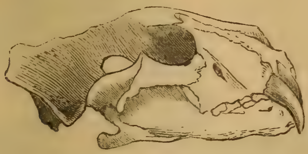
forms around us, and by acquiring an intimate knowledge of their osseous framework or skeleton, that we can hope to decipher the handwriting on the rock, obtain a clue to guide us through the labyrinth of fossil anatomy, and conduct to those interesting results, which the genius of the immortal Cuvier first taught us how to acquire. And here it will be necessary to enter upon the consideration of those admirable principles of the correlation of structure in organized beings, that were first announced by that illustrious philosopher, and which form the basis of all palæontological knowledge.

The organs of every animal, observes Baron Cuvier, must be regarded as forming a machine, the parts of which are mutually dependent on each other, and exquisitely adapted for the functions they are destined to perform; and such is the intimate relation of the several organs, that any variation in one part, is constantly accompanied by a corresponding modification in another. This correlation, or mutual adaptation of the several parts of the animal fabric, is a law of organic structure, which, like every other induction of physical truth, has only been established by patient and laborious investigation. It is by the knowledge of this law that we are enabled to reassemble, as it were, the scattered remains of the beings of a former state of the globe,—to determine their place in the scale of animated nature,—and to reason on their organization, habits, and economy, with as much clearness and certainty, as if they were still living and before us.

I will demonstrate this proposition by a few examples. Of all the solid parts of the animal frame the most obviously mechanical are the jaws and teeth; and as we know in each instance the offices they are intended to perform, these organs afford the most simple and striking illustration of the principles above enunciated.

12. Osteology of the carnivora.—If we examine the

jaws of the skulls before us, those, for example, of a Bengal Tiger (*Lign.* 18), and of a Cat (*Lign.* 19), we perceive that there are cutting teeth in front, sharp fangs on the sides, and molar, bruising, or crushing teeth, in the back part. The



Lign. 18.—Skull of the Bengal Tiger.

molars rise into sharp lanciform points, and overlap each other in the upper and lower jaw, like the edges of a pair of shears; and the teeth are externally covered with a thick crust of enamel. This is evidently an apparatus for tearing and cutting flesh, or for cracking bones; but is not suited for grinding the stalks or seeds of vegetables. The jaws fit together by a transverse process or joint, which moves in a corresponding depression in the skull, like a hinge; they open and shut like shears, but admit of no grinding motion; this, then, is such an articulation as is adapted for a carnivorous animal; and every part of this instrument is admirably fitted for its office.

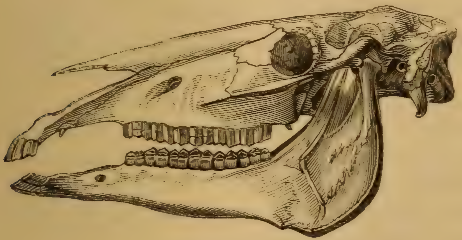
But all these exquisite adjustments would be lost, were there not levers and muscles to work the jaws,—were not each portion of the animal frame adapted to all the other parts,—and were not the instincts and appetites of the animal such as are calculated to give to this apparatus its appropriate movements.

Let us reverse the order of the argument,—let us assume that the stomach of an animal be so organized as to be fitted for the digestion of flesh only, and that flesh recent,—we should find that its jaws would be so constructed as to fit them for devouring live prey,—the claws for seizing and tearing it,—the teeth for cutting and dividing it,—the whole

Lign. 19.—Skull of a Wild Cat.
(*Felis Canadensis.*)

system of its powers of motion for pursuing and overtaking it,—the organs of sense for discovering it at a distance,—and the brain endowed with the instinct necessary for teaching the animal how to conceal itself, and lay snares for its victims. Such are the general relations of the structure of carnivorous animals, and which every being of this class must indispensably combine in its constitution, or its race cannot exist. But subordinate to these principles, are others connected with the nature and habits of the prey upon which the animal is intended to subsist, and thence result modifications of the details in the forms which arise from the general conditions. Thus, in order that the animal may have the power requisite to carry off its prey, there must be a certain degree of vigour in the muscles which elevate the head; and thence results a determinate form in the vertebræ or bones from which these muscles originate, and in the back of the skull in which they are inserted. That the paws may be able to seize their prey, there must be a certain degree of mobility in the toes, and of strength in the claws, and a corresponding form in all the bones and muscles of the foot. It is unnecessary to extend these remarks, for it will easily be seen that similar conclusions may be drawn with regard to all the other parts of the animal.* In the Tiger and the Cat, (*Ligns.* 18, 19,) we have a familiar illustration of what has been advanced.

13. OSTEOLOGY OF THE HERBIVORA.—In animals which are destined to live on vegetables we have the same mutual relations; the sharp fangs of the teeth are wanting; the enamel is not all placed on the top of the teeth as in the carnivora, but arranged in deep vertical layers, alternating with bony matter; and this arrangement secures, in all states of the teeth, a rough grinding surface, as in the horse and the elephant. The flat molar teeth are not formed for



LIGN. 20.—SKULL OF THE HORSE.

cutting, but for mastication, and the jaws are loosely articulated together, so as to allow of a grinding movement; had the socket and corresponding part of the jaw been the same as in the tiger, the teeth could not have performed their office; in the skull of the horse (*Lign.* 20), this modification of structure is exemplified. Again, I might

* Consult Cuvier's "Discours sur les Révolutions;" "Leçons d'Anatomie Comparative;" "Ossemens Fossiles," &c.

proceed in the argument, and show the adaptation of the muscles of the head to the apparatus here described ; and, beginning with the jaw, review the whole animal frame, and demonstrate how all its parts are alike wonderfully constructed and fitted together, to perform the functions necessary for the being to which it belongs.

In the Elephant, which has but four teeth in each jaw, the deficiency of prehensile incisor teeth being supplied by that wonderful instrument, the proboscis, or trunk, the structure of the dental organs is still further modified. The teeth of animals are formed of three distinct substances, which are variously disposed in the different orders, according to the habits and economy of the species. The nucleus, or germ of the tooth, is a congeries of blood-vessels and nerves, called the *pulp*, by which the calcareous hard parts are elaborated. The pulp is surrounded by a covering of a very dense substance, composed of phosphate of lime, with albumen and gluten, termed dentine, or tooth-ivory, which is permeated throughout by very minute tubes. The dentine is encased in a still harder material, called *enamel*. In the teeth of man, and of the carnivora, the enamel covers the entire external surface of the crown. There is a third substance, a coarse kind of dentine, of an opaque and yellowish appearance, termed *crusta petrosa*, or cement, which, in the Elephant and other herbivora, is interstratified with the enamel and dentine. The intermixture of these three dental elements—the tooth-ivory, cement, and enamel—is apparent on the worn surfaces of the teeth of elephants ; and it differs in the several recent and fossil species.*

In the African elephant, (*Lign.* 21, *fig.* 1,) the worn surface of the molar teeth presents a series of lozenge-shaped lines of enamel, having the dentine on the inner margin of the ridges, and being surrounded by the *crusta petrosa*. In the Asiatic

* See "Medals of Creation," vol. ii. p. 837 ; "Teeth of Mammalia."

species (*fig.* 3) the enamel forms narrow transverse bands; and the tooth of the Mammoth, or fossil elephant, (*fig.* 2,) has an analogous, but somewhat different distribution.

1 2 3

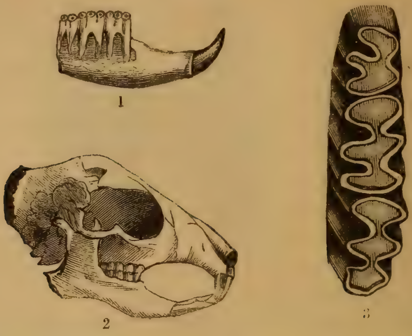
LIGN. 21.—GRINDING SURFACE OF TEETH OF ELEPHANTS.

Fig. 1. The worn surface of the crown of a tooth of the African Elephant. Fig. 2. Grinding surface of a tooth of the Mammoth, or fossil Elephant. Fig. 3. Grinding surface of the Asiatic Elephant.

The appearances shown in these horizontal sections of the crown of the teeth, arise from the dentine being disposed in parallel and vertical plates which have an immediate investment of enamel, and are bound together by an external layer of cement that envelopes the entire series, which often consists of from twenty to thirty plates. By this peculiar modification of structure, a rough grinding surface, adapted for the mastication of vegetable food, is always maintained, from the unequal wearing away of substances of such different degrees of hardness.

14. DENTAL ORGANS OF THE RODENTIA, OR GNAWERS.—In the jaws of an intermediate order of animals, we find new modifications of the same apparatus. Thus the *Rodentia*, or gnawers, have long sharp cutting teeth, like nippers; it is by these instruments that the rat can speedily gnaw a hole through a board, and the squirrel in a nut, in

consequence of their exquisite adaptation for these operations. In the skull of the Squirrel (*Lign.* 22, *fig.* 2) the front teeth are of enormous size, as compared with the



LIGN. 22.—SKULL AND TEETH OF RODENTIA, OR GNAWERS.

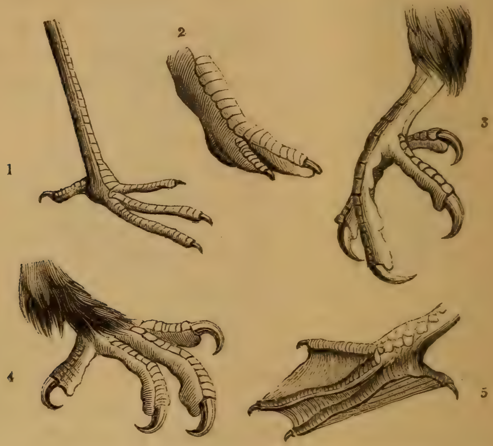
Fig. 1. Inner side of the left lower jaw of a Florida rat, (*Arvicola Floridana,*) of the natural size.
2. Skull of the Squirrel.
3. Molar teeth of the upper jaw of a Florida rat, magnified; seen obliquely.

molar, and they lock together in such manner as to render a grinding movement impossible; a corresponding adjustment, therefore, takes place,—the lower jaw is so constructed as to work in the skull neither in a transverse nor in a rotatory direction, but lengthwise, like the action of a carpenter using his plane, the teeth moving backwards and forwards; as may be observed in the rabbit while eating its food. The enamel of the molar teeth, as for example in those of the Rat, (see *Lign* 22, *fig.* 3) is placed vertically and transverse to the jaw, so as to form an admirable grinding surface. But this is not the only variation of structure observable in these teeth. The incisors being implements of constant use, are renewed by continual growth, and there is a special provision for their support in a bent socket.

The enamel is unequally distributed round the tooth, being very thin behind and thick in front, by which means the cutting edges are always preserved; for by the act of gnawing, the hinder part of the incisor wears away quicker than the fore part, and thus a sharp inclined edge, like that of an adze or chisel, is maintained, and which is the very form required in the economy of the animal. The teeth of the common rabbit or hare will exemplify these remarks.

15. General inferences.—These are but a few instances of those admirable adaptations of means to ends, which are observable throughout the various classes of organized beings: but the limits of a single lecture will not admit of more examples, and it is, I trust, unnecessary to offer additional proofs, that the conclusions of geologists as to the nature of the ancient inhabitants of our globe, are not vague assumptions, as those unacquainted with the science might suppose, but the legitimate deductions of laborious and patient investigations. A few teeth and bones—sometimes but a single relic of this kind—are the elements by which the palæontologist is enabled, not only to restore the forms of creatures now banished from the face of the earth, but also to ascertain their habits and economy, and even arrive at positive conclusions respecting the nature of the country of which they were once the inhabitants. If we find the remains of animals which were herbivorous, it follows that there must have been a condition of nature calculated for the growth of vegetable productions for their subsistence; a suitable soil and climate, and a country diversified by hills, valleys, and plains, with streams and rivers to carry off the superfluous waters.

The same laws, under certain modifications, apply to other classes of beings. In birds, the form of the feet is modified according to the habits of the different orders. In the parrot, (*Lign.* 22, *fig.* 3,) the claws are adapted to climb trees and perch on the branches; but in the eagle they are widely different, for its talons are constructed to lacerate and tear its prey (*fig.* 4). The feet of aquatic birds are formed like a paddle or oar, to enable them to



LIGN. 23.—DIFFERENT FORMS OF FEET IN BIRDS.

Fig. 1. Foot of the Heron; Fig. 2. of the Ostrich; Fig. 3. of the Parrot; Fig. 4. of the Eagle; Fig. 5. of the Pelican.

make their way through the water (*fig.* 5); those of birds that frequent marshes have a great expansion, like a tripod, that they may move over the unstable surface of the morass (*fig.* 1); while in species destined to inhabit sandy deserts, as the Ostrich (*fig.* 2), the feet present a corresponding modification of structure.

We perceive, therefore, that every vertebrated animal has a solid and durable skeleton, or osseous support, formed upon one general plan, but modified in almost endless variety, in the relative magnitude, situation, and aspect of the different parts, so as to adapt itself to the various habits and functions of the diversified forms of animal life. In short, that the Author of nature has by these changes varied the same general fabric in innumerable ways, bestowed upon it a thousand different instincts and passions, and adapted it to every element and climate, and to every possible variety of food and mode of existence; and it is by a profound knowledge of these principles of the correlation of the different parts of every organized creature, that the scientific observer is enabled to reconstruct the forms of extinct animals.

We may now enter upon that department of geology called *Palæontology*, or the science which treats of the fossil remains of the beings which inhabited our planet in former ages.

16. Fossil elephants, &c.—As the bones and teeth are the least perishable parts of the animal structure, they are in general the only indications of the characters of the ancient mammalia. Occasionally very delicate parts, such as the tunic of the eye, the membranes of the stomach, the hair and integuments of the skin, &c. are preserved in a fossil state, examples of which we shall hereafter adduce. In the older rocks, the bones are generally mineralized, and no longer possess the white and glossy appearance of the recent skeleton; but those which occur in superficial gravel, and in caverns, are commonly of a porous and earthy character, like bones that have lost a portion of their animal matter by being buried in a dry and loose soil.

The fossil bones and teeth we have now to examine are separable into two classes, namely, those which occur in the gravel, marl, &c., of the drift and alluvial deposits, and those buried in fissures and caverns. The former are principally referable to herbivorous pachyderms and ruminants; the latter to carnivora.

I will first take a brief review of the remains of the large herbivora, especially of those allied to the elephantine family, which occur in great abundance, and are very generally distributed throughout Europe, Asia, and America. In the earlier ages, these colossal bones were supposed to belong to gigantic races of mankind, and gave rise to the marvellous traditions of giants, so rife in every country in Europe; but we need not smile at the ignorance and credulity of our ancestors, for, not many years since, a fossil tooth of an elephant, found in digging a well in Brighton, was supposed to be a petrified cauliflower!

In Russia, and more especially in Siberia, the fossil bones of extinct species of Elephants, and other mammalia, are found throughout all the low lands, and in the sandy plains which extend from the borders of Europe to the nearest extreme point of America, and south and north from the base of the mountains of central Asia, to the shores of the Arctic sea. Within this space, which is almost equal in extent to the whole of Europe, fossil ivory is everywhere to be found; and the tusks are so numerous and well preserved, especially in Northern Russia, that thousands are annually collected, and form a lucrative article of commerce. In Siberia alone, the remains of a greater number of elephants have been discovered, than are supposed to exist at the present time all over the world.*

17. FOSSIL MAMMALIA OF THE VALLEY OF THE THAMES.—It may appear astounding to some of my readers to treat of elephants, rhinoceroses, hippopotami, and gigantic elks,

* In 1844, a company of merchants was formed to collect teeth and tusks of mammoths from Siberia; for the fossil ivory was found to possess all the qualities of the recent, and at the same time was less liable to turn yellow. During the year, sixteen thousand pounds of jaws and tusks of mammoths were obtained, and these were sold at St. Petersburg, under the denomination of Siberian ivory, at prices from 30 to 100 per cent. above those of recent elephantine ivory.

as having formerly inhabited the country irrigated by the Thames; yet such was unquestionably the case at no very remote epoch, when probably the land of England was united to the Continent, and the river extended over a much larger area than it has occupied since many centuries before the Roman advent.

The banks of the Thames, and of its tributary streams, are in great part composed of an ancient alluvial silt or brick-earth, many yards in thickness, containing, in certain localities, mammalian bones in considerable abundance, with interspersions of existing species of land and river shells.* At Erith this deposit reaches to 40 feet above the river, and near Maidstone to 60 feet.

At Grays in Essex (opposite Gravesend) these deposits may be seen to advantage in sections exposed in the extensive brick-fields. The beds consist of—1. Gravel and sand; 2. Loamy sand and brick-earth; 3. Ferruginous sand, shells, and gravel; 4. The Chalk, which forms the foundation rock of the country. From this locality alone have been obtained numerous bones of the Elephant, Rhinoceros, Hippopotamus, Horse, Ox, Deer, Irish Elk, Vole, Bear, Hyena, and Monkey.

Scarcely any traces of trees or plants have been met with, yet it is obvious that the country which supported these large herbivora, must have had an abundant vegetation.

18. Fossil elephants of other parts of England.—Along the eastern coast of England, and off the mouth of the Thames, teeth, tusks, and bones of elephants and other mammalia, are often dredged up by the fishermen, having

* There is a species of *Cyrena,* supposed to be identical with one that now exists in Alexandria; and an *Unio,* of which the analogue lives in the lakes and rivers of Auvergne: neither are known as British species. See a highly interesting memoir on these deposits, and their fossil remains, by John Morris, Esq. (of Kensington), author of "A Catalogue of British Fossils," &c.; Mag. Nat. Hist. vol. ii. p. 539.

been washed out of the alluvial deposits of the neighbouring cliffs by the action of the sea; for the same kind of drift and alluvial detritus is spread over the country along the maritime districts of Essex, Suffolk, Norfolk, and Yorkshire.

At Herne Bay, in the embouchure of the Thames, great numbers of mammalian bones have been found; Walton in Essex is still more prolific; and the late Mr. Woodward informed me, that the elephants' teeth which had come under his observation from the coast of Norfolk must have belonged to more than 500 individuals.

On the western coast of Sussex, and in the neighbourhood of Arundel, Patcham, and Brighton, teeth and bones of elephants have at different times been exhumed. At Brighton the teeth are found in a deposit of water-worn materials, consisting of loam, chalk, and broken flints, resting on a bed of shingle covering the chalk.* In the conglomerate, of which I have already spoken (p. 114), as well as in the superincumbent deposits, teeth of elephants, with teeth and bones of a species of deer, horse, and whale, occur, and are associated with marine shells;† similar fossils are found in deposits of a like character along the opposite coast of France.

These elephantine remains are, in the opinion of Dr. Falconer, referable to three species: but the greater number belong to the Mammoth, or fossil Elephant of Siberia.

With these relics of extinct animals are found those of many species which still inhabit England, as the Badger, Otter, Polecat, Weasel; and of others which were contemporary with the earliest British tribes, as the Irish Elk, Bear, Beaver, Wolf.‡

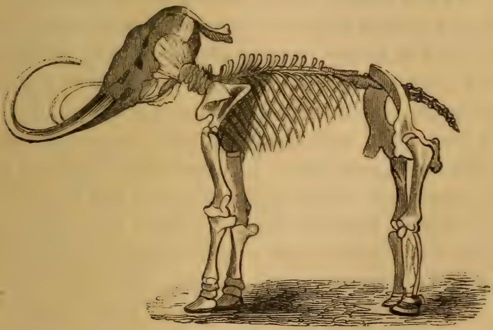
* See Geology of the South-East of England, p. 32.

† Medals of Creation, vol. ii. p. 824, for an account of the discovery of the fossil jaw of a Whale in Brighton Cliffs.

‡ In the fenny district of Cambridgeshire, these and other mam-

19. Extinct Elephant, or Mammoth,* in ice.—There are but two species of existing Elephants, namely, the African, which ranges as far south as the Cape of Good Hope, and the Asiatic, which is limited to within 31° north latitude. Yet the remains not only of one, but of several extinct species of this family, occur all over Europe and North America, and are imbedded in frozen gravel and drift in 72° north latitude. They even abound in ice-cliffs on the north-west angle of the American Continent, near to Behring's Straits.

The occurrence of innumerable relics of huge extinct herbivorous mammalia, over vast regions of the icy zone, where but few forms of animal life can now subsist, is a fact of so much interest in every point of view, as to



Lign. 24.—Mammoth, or Elephas primigenius; found imbedded in frozen gravel in Siberia.

(Twelve feet high, and sixteen feet long.)

demand our earnest attention. For not only are the bones and tusks found in a beautiful state of preservation, but

malian remains have been found. See Professor Owen's History of British Mammals; and my Medals of Creation, vol. ii.

* A Russian term applied to the fossil Elephant.

sometimes even the entire body, with the flesh and skin, as fresh as if but recently imbedded.

In 1774, near Vilhoui, the carcass of a rhinoceros was taken from the frozen sand, where it must have been concealed for ages, the soil of that region being always frozen to within a few inches of the surface. This specimen was a complete natural mummy, part of the skin being still covered with long hairs, and forming a warmer covering than that of the African rhinoceros.

The discovery of a Mammoth under similar circumstances, is yet more interesting. Towards the close of the last century, 1799, a Tungusian fisherman observed in a cliff of ice and gravel, on the banks of the river Lena, a shapeless mass, the nature of which he was unable to determine. In the course of the next year it was more visible, and on the third a large tusk was seen projecting from the ice-cliff, and at length became detached. On the fifth year, an early thaw set in, and the entire carcass of a mammoth was exposed, and at length fell upon the ground. It was twelve feet high, and about sixteen feet in length; the tusks were nine feet long. The flesh was in such a state of preservation, that it was devoured as it lay by wolves and bears, and the hunters fed their dogs with the remains. The skin was covered with hair consisting of black bristles, thicker than horsehair, and fifteen inches in length; of wool of a reddish brown, and hair of a fawn colour; and with a mane on the neck. Upwards of 30lbs. of hair were collected; some specimens of which are preserved in the Hunterian Museum of the College of Surgeons. The ears remained dry and shrivelled; the brain and even the capsule of the eye were preserved! the bones and part of the integuments, and a considerable quantity of the hair, are in the Museum of Natural History at St. Petersburgh. The accompanying sketch (*Lign.* 24) represents the specimen in its present state.

The tusks are curved forward and upward. The teeth differ from those of the two living species of Elephants, in the disposition of the plates of dentine (see p. 142), and also in their internal microscopic structure ; the configuration of the skull is likewise peculiar ; and these discrepancies, together with the hairy and woolly skin, led Baron Cuvier to consider the species as having been adapted to exist in a colder climate than the living types. But that eminent philosopher also assumed, from the preservation of the bodies of these animals in ice, and the present low temperature and sterile condition of that part of Siberia where these remains abound, that a sudden change of climate had taken place, and continued, by which the race was destroyed, and entombed in the frozen soil.

Playfair, with that profound sagacity which characterized all his speculations on geological phenomena, first suggested the idea, "that the power of living in a different climate, and of enduring greater degrees of heat or of cold, and of subsisting on a different kind of food," may have belonged to the extinct Elephants found in Siberia ; "for though one species," he remarks, "may now be confined to the southern parts of Asia, another may have been able to endure the severe climates of the north : and the same may be true of the rhinoceros, buffalo, &c. These animals may have lived farther to the south than where their remains are actually found, among the valleys between the great ranges of mountains that bound Siberia on that side. We must observe, too, that they may have migrated with the seasons, and by that means avoided the rigorous winters of the high latitudes."* And more recently, Mr. Lyell, extending these views, suggested that a large region of Central Asia, perhaps the southern half of Siberia, might, during the Mammoth period, have possessed a climate mild

* Playfair's Illustrations of the Huttonian Theory, Edinburgh edition of 1822, vol. i. p. 465. Dr. Fleming also supported these views.

enough to support a vegetation fit for the sustenance of the fossil species; and reasoning upon the present physical geography of the country, that the whole tract from the Ural mountains to the sea, had been upraised, like Sweden (p. 116); and that the refrigeration of the north-east of Asia, and its present condition, were the result. These opinions have been confirmed by the recent investigations of Sir R. Murchison, which are so important, both in a geological and palæontological point of view, that I must offer a concise sketch of the facts and observations which bear upon this question.

20. Mammoths of the alluvial deposits of Russia.—Premising, that with the remains of the Mammoth and Rhinoceros, there occasionally occur bones of a gigantic Beaver (*Trogontherium*), Bear, Elk, Ox, and a remarkable extinct pachyderm (*Elasmotherium*), we will first describe the nature of the deposits in which these relics are imbedded.

There is a great analogy in the geological character of the detritus composing the alluvial mammalian beds of Russia and those of our own island; both have evidently been formed under similar circumstances in river deltas, and in estuaries, and off sea-shores, in water of moderate depth; they are in fact drifted materials that were brought down by currents and streams, from the dry lands inhabited by the animals whose remains they contain: and by the subsequent elevation of the coasts these littoral deposits have been raised to their present level.

In Siberia, the mammoth's remains are found in alluvial detritus in the flat northern tracts, or near the mouths of the great rivers. Even in all the central and southern parts of European Russia, from there being no high ridges of elevation, and consequently no coarse local detritus as on the flanks of the Ural mountains, the Mammoth alluvium assumes the same aspect as in the distant plains of Siberia, where it is equally removed from disturbing causes.

A section exposed in an abrupt cliff on the sea of Azof, at Taganrog, will explain the usual character of the deposits :*—

1. Tertiary newer miocene limestone : forming the base of the cliff: 20 feet.
2. Band of finely laminated sands, full of shells, specifically identical with those that inhabit the adjacent river Don.
3. Clay drift, containing numerous bones and teeth of the Mammoth : 50 feet.

From the nature of this drift, and its distribution at various levels, Sir R. Murchison infers that the greater part of this low continent, unlike the Ural and higher portions of Siberia, was not dry land during the existence of the Mammoths, nor in the period immediately antecedent to our own ; but was in the same subaqueous condition as the low lands of Northern Siberia, when the bones were transported into the then existing estuaries and bays.

21. Siberia and Russia in the mammoth epoch.—These observations of Sir R. Murchison clearly prove, that the mammoths cannot have inhabited the northernmost tracts of Siberia in which their remains are imbedded, for the wide and low tracts of that sterile region were beneath the sea at the period when these extinct animals existed ; the bones and carcasses must, therefore, have drifted thither, and probably from a considerable distance. The mammalian remains do not occur on the elevated chains of hills ; and from the physical structure of the region, it is probable that not only the Ural and Altai mountains, but also their northern ridges and terraces, which include more than half of Siberia, were covered with forests in some parts, and with brushwood steppes in others ; and herds of mammoths may have migrated thence in the summer season, (which is even now intensely hot,) to the

* Geol. Russ. vol. i. p. 502.

embouchures of the great streams, and the borders of the then Arctic sea. Sir R. Murchison proceeds to remark that—

"A former terrestrial surface, on which the great quadrupeds lived for ages, and the rupture and diminution of adjacent lakes, coincident with some of the last elevations of the Ural chain, will best explain the condition in which the remains of mammoths are left buried on the edges of the uplifted ridges of the Ural, as well as in the low lands and great estuaries farthest removed from them.

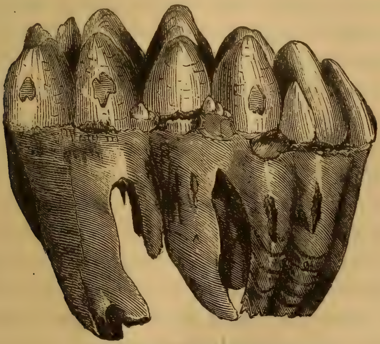
"As we advance into the plains of Siberia, or descend into the valleys of the Tobol and the Obe, the bones are in greater quantities and in a better state of preservation; and the farther the Siberian rivers are followed to their mouths, the more do the mammalian remains increase, until at length whole skeletons, and even carcasses, are found. The single fact of the very wide diffusion of mammoth bones over enormous regions, in itself indicates that those creatures had long been inhabitants of such countries, living and dying there for ages; whilst their final destruction may have resulted from aqueous debacles dependent on oscillations of the land, the elevation of mountain chains, and the formation of much local detritus.

"The Siberian mammoth, having a close coating of wool and much shaggy hair, seems to have been adapted to inhabit the regions of northern Europe and Asia; and the elevation of large tracts of land in Siberia, by laying dry the low shores and estuaries into which their bones had been washed, would necessarily render the climate more intensely cold. The intimate structure of the teeth in the mammoth differs from that of the Asiatic and African elephant, and is supposed by Professor Owen to indicate that the extinct creature lived on coarser ligneous tissue of trees and shrubs, that may have constituted forests, extending even into the promontories of the icy sea, ere the physical events which elevated the Ural mountains to their present altitude, and left the coasts with no vegetable support but the moss and lichens for the rein-deer, with which the mammoths were once contemporary."*

22. THE MASTODON.—In various parts of North America, there are marshy tracts abounding in salt and brackish waters, that are frequented by deer, and other animals;

* From a masterly review of the phenomena relating to this subject, by Sir R. I. Murchison,—"Geology of Russia," vol. i. chap. xix.

a circumstance from which these swamps have acquired the American name of *Lick.* In these morasses vast quantities of bones and several entire skeletons of elephants and other gigantic quadrupeds have been discovered. The spot most celebrated for these remains in Kentucky, is called Big-bone Lick, which is situated to the south-east of the Ohio, in the midst of a group of low hills, and is traversed by a small stream of brackish water. The bottom consists of black fetid mud, intermingled with sand and vegetable matter; and in this bog, bones occur in abundance. Some of them are referable to the mammoth; but others, as you may observe from the specimens before us, belonged to a creature not less gigantic, but with very distinct characters. These teeth are composed of dentine and enamel; and the latter is spread over the crown of the tooth, which, before it is



Lign. 25.—Tooth of the Great Mastodon, from the banks of the Hudson; weight 4lbs; one-third natural size linear.

(Mastodon giganteus.)

worn by use, is divided into several transverse tubercles, or processes, each of which is subdivided into two obtuse points, these transverse ridges not being filled up with cement, as in the elephant; from this form of the crown of the tooth the animal to which it belonged has received the name of MASTODON, signifying mammillary tooth. These teeth have no relation whatever to those of the carnivora; for though they have an external investment of enamel as in the teeth of the tiger, they are destitute of the longitudinal, serrated, cutting edge; and in those which are worn, the protuberances become truncated into a lozenge form. This structure is fitted for the grinding and mastication of tough and hard vegetable substances. The bones and teeth of the mastodon have been found throughout the plains of North America, from north of Lake Erie to as far south as Charleston in South Carolina; they have also been discovered on the Continent, and in the Crag of England, and in several parts of India. Here are examples from the banks of the Ohio and Hudson; and from Big-bone Lick; one of these is a perfect tooth of a young aninal; but this specimen must have belonged to a very old one, for the grinding surface is worn almost flat by use.

These remains are found in marl, beneath peat bogs, at moderate depths, and with no marks of attrition; it is therefore evident that the animals lived and died in the country where their relics are entombed.

In the suburbs of Rochester (U. S.) many bones of Mastodons were dug up from a bed of clay which contained numerous shells of existing river species (*planorbis*, *valvata*, *limnea*, *cyclas*, &c.). The skeletons of the great mastodon found in the bogs of Louisiana were in a vertical position, as if they had sunk in the mire; and one discovered imbedded in black earth, in New Jersey, forty miles to the south of New York, was in the same position, the head being on a level with the surface of the soil. There is now an entire skeleton of the mastodon in the British Museum. From this specimen it appears that the great mastodon of the Ohio was not unlike the elephant in its general outline, though somewhat longer and thicker.

It had a trunk or proboscis, tusks, which curved upward, and four molar teeth in each jaw, but no incisors.

But another remarkable peculiarity, and which entirely separates the mastodon from the elephant, is that the young animal had a pair of tusks, placed horizontally in the lower jaw, and of these tusks, one only became developed, and that in the adult male; both were early shed in the female.* In the midst of a collection of mastodon bones imbedded in mud, a mass of small branches, grass, and leaves, in a half bruised state, and a species of reed, common in Virginia, were discovered; the whole appeared to have been enveloped in a sac, probably the stomach of the animal. In another instance, traces of the proboscis were observed. The tusks are composed of ivory, and vary somewhat in the direction and degree of their curvature. The bones of this colossal quadruped are found remarkably fresh and well preserved, and are generally impregnated with iron. No living instance of this creature is on record, and there can be no doubt that its race has long since been extinct. The Indians believe that men of equally gigantic proportions were coeval with the mastodon, and that the Great Spirit destroyed both with his thunder.† There are several species, some of which have been found in North America only, and others in Europe. Baron Humboldt discovered a tooth of the mastodon near the volcano of Imbaburra, at an elevation of 1,200 fathoms. In England, a few teeth have been found in the Norwich Crag; these belong to a species named Mastodon angustidens (*narrow-toothed*).‡

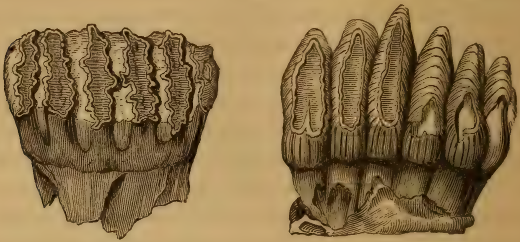
23. Mastodons from Ava.—I have now to call your attention to the fossil remains of several species of mas-

* Professor Owen.

† Cuvier. Oss. Foss.

‡ The British Museum now contains an unrivalled collection of the fossil remains of mastodons and mammoths from North and South America, and India.

todons which, from the structure of the teeth, fill up, as it were, the interval that separates the mastodon from the elephant; one of these was in consequence named by Mr. Clift, *Mastodon elephantoides*, (*Lign.* 26, *fig.* 2.) These



1 2

LIGN. 26.—FOSSIL TEETH OF THE ELEPHANT AND MASTODON.

(*One-sixth the diameter of the originals.*)

Fig. 1. Tooth of the *Elephas primigenius*, from Big-bone Lick.
2. Tooth of the *Mastodon elephantoides*, from near Ava.

teeth present very peculiar characters; for while in their general appearance they resemble those of the mastodons already described, the crown of the tooth is deeply ridged, and the dentine and enamel are invested with so large a portion of cement, as to give the worn surface of the crown, the aspect of the molars of the true elephant.

The specimens before us, consisting of teeth and bones of mastodons, elephants, hippopotami, rhinoceroses, horses, tapirs, antelopes, gavials, fresh-water turtles, &c. and silicified wood, are part of an extensive collection formed about twenty years since by Mr. Craufurd, on his mission to Ava. In descending the river Irawaddi, his steam-boat, owing to the shallowness of the water, ran aground between Prome and Ava, about 20° north latitude, near some petroleum wells, where the bank of the river presented a cliff

80 feet high; and on the strand were observed masses of petrified wood, and vast quantities of bones. The adjacent country is formed of low, sterile sand-hills, intersected by ravines, with beds of gravel, which are here and there cemented into a conglomerate by iron and carbonate of lime. Scattered over the surface, in some instances lying loose in the sand, and in others half buried, were masses of silicified wood, and fragments of bones, which had become exposed, from the removal of the sand by the winds and rains. The bones are more or less invested with a hard crust, which is a concretion formed by the consolidation of loose sand from ferruginous and calcareous infiltrations. The natives who assisted Mr. Craufurd's party in collecting these remains, believed them to be the bones of giants that had warred against Vishnu, by whom they were destroyed.

24. Fossil mammalia, &c. of the Sub-Himalayahs. —But the number of these transitional or intermediate links of elephantine forms, has been greatly increased by the accession made to our knowledge of the fossil fauna of India, by the labours of Major Proby Cautley, and Dr. Falconer, who, with energy and perseverance beyond all praise, formed, and brought to Europe, an immense collection of these mammalian remains. The following extract from the prospectus of a work now in the course of publication by these eminent naturalists, will convey some idea of the richness and interest of their discoveries:—

"The fossil Fauna of the Sewalik range of hills, skirting the southern base of the Himalayahs, has proved more abundant in genera and species of mammalia than that of any other region yet explored. As a general expression of the leading features, it may be stated, that it appears to have been composed of representative forms of all ages, from the *oldest of the tertiary period down to the modern;* and of *all the geographical divisions of the Old Continent,* grouped together into one comprehensive Fauna. Of the forms contained in it may be enumerated, in the *Pachydermata,* several species of Mastodon and Elephant, Hippopotamus, Rhinoceros, Anoplotherium, Sus, and three species of Equus; in the *Ruminantia*, the colossal genus Sivatherium, peculiar to India, with species of Camelus, Camelopardalis, Bos, Cervus, and Antelope; in the *Carnivora*, species of most of the great types, together with several remarkable undescribed genera; in the *Rodentia*, several species; in the *Quadrumana*, several species; in the *Reptilia*, a Gigantic Tortoise (*Colossochelys*), with species of Emys and Trionyx, and several forms of Crocodile. To these may be added the fossil remains of struthious and other Birds, Fishes, Crustacea, and Mollusca." *

25. SUB-HIMALAYAH TERTIARY DEPOSITS.—The deposits from which these remains were obtained resemble those of Ava, and consist of concretionary grit, conglomerate, sandstone, and loam; they are spread over the flanks of a range of hills belonging to the Sub-Himalayan mountains, between the river Sutlej and the Ganges. These hills, which are called Sewalik (from Siva, an Indian deity), rise to an altitude of from one to three thousand feet above the level of the sea. The alluvial deposits extend about 200 miles in length, and seven in width, and dip to the north at an angle of 25°; wherever gulleys or fissures expose sections of the beds, abundance of fossil bones appear.† Lignite, and trunks of dicotyledonous trees occur; a few land and freshwater shells of existing species, are the only vestiges of mollusca that have been observed. Remains of several species of river-fish, some related to the recent Silurus, have been obtained.

The immense collection of these fossils in the British Museum, renders any detailed description unnecessary, and I will only dwell on a few of the most important particulars.

The remains of the Elephants and mastodontoid animals,

* "*Fauna Antiqua Sivaliensis*, or the Fossil Zoology of the Sewalik Hills, in the north of India, by Hugh Falconer, M. D. and Major P. T. Cautley."

† See an interesting Memoir by Major Cautley; Geol. Trans. 2d Series, vol. v. p. 267.

comprise perfect specimens of skulls, and jaws, of gigantic size. The tusks of one example are 9 feet 6 inches long, and 27 inches in circumference at the base.*

26. Remarkable Collocation of Fossil Animals.—But this collection is invested with the highest interest, not solely on account of the number and variety of the specimens, but, also, for the extraordinary assemblage of animals which it presents. In the Sub-Himalayahs we have entombed in the same rocky sepulchre, bones of the most ancient extinct races of mammalia, with species and genera which still inhabit India! Palæotheria, Anoplotheria, Dinotheria, Mastodons, Elephants, Giraffes, Hippopotami, Rhinoceroses, Horses, Camels, Antelopes, and even Monkeys; Struthious Birds, and Crocodilian and Chelonian reptiles. To this concise enumeration must be added several genera previously unknown; large rodents, and insectivora, &c.

Among these marvellous relics of the past, are the skull and bones of an animal named *Sivatherium* (from the Indian deity *Siva*), that requires a passing notice. This creature forms, as it were, a link between the ruminants and the large pachyderms. It was larger than a rhinoceros, had four horns, and was furnished with a proboscis; thus combining the horns of a ruminant with the characters of a pachyderm. When living, it must have resembled an immense antelope, or gnu, with a short and thick head, and an elevated cranium crested with two pairs of horns; the front pair were small, and the hinder large, and set quite behind, as in the aurochs; with the face and figure of the

* These fossils are so admirably cleared from the hard rock with which they were incrusted (a task of no little labour, and requiring great skill), that I cannot forbear recommending to the notice of any collectors who may require such aid, the person by whom they were chiselled out—*James Dew, 25, Harrison Street, Gray's Inn Road.*

rhinoceros, it had small lateral eyes, great lips, and a nasal proboscis.

Among the reptilian remains are skulls and bones of a Gangetic Crocodile or Gavial, and of a land Turtle, which cannot be distinguished from those of species still living in India. But the most extraordinary discovery is that of bones, and portions of the carapace, of a Tortoise of gigantic dimensions ; it has been aptly named *Colossochelys Atlas:* the length of this reptile exceeded *twelve feet.*

27. THE PAMPAS.—The Pampas, those vast plains in South America, which present a sea of waving grass for 900 miles, are principally composed of alluvial loam and sand containing freshwater and marine shells, and were once, like Lewes Levels, a gulf, or arm of the sea. In these alluvial deposits, bones of enormous extinct mammalia have frequently been discovered. Towards the close of the last century, an almost perfect skeleton of a gigantic animal (*Megatherium*), was dug up, at a considerable depth, in a bed of clay, on the banks of the river Luxor, about four leagues W.S.W. of Buenos Ayres. This skeleton was sent, in 1789, to the museum at Madrid, where it now remains. It is described and figured by Cuvier, under the name of *Megatherium.*

In 1832, Sir Woodbine Parish, with considerable labour and expense, collected many bones of a similar creature from the Salado ; having actually diverted for a time the river from its course, that he might disinter these remains ; these he afterwards presented to the Museum of the Royal College of Surgeons of England.

Since that time relics of several other remarkable forms of extinct mammalia have been discovered ; a few of these we will here briefly describe.

The Pampas, observes Mr. Darwin, may be regarded as one vast sepulchre of these lost quadrupeds. The deposits in which the bones occur are as follow :—

1. Clay, sand, and limestone, containing marine shells and shark's teeth, forming the substratum.

2. Indurated marl.

3. Red clayey earth with calcareous concretions and bones of terrestrial animals.

This section demonstrates that a bay of salt-water was gradually encroached upon, and at length became the bed of a muddy estuary, into which floated the carcases of the animals which then inhabited the neighbouring dry land. It is in the upper deposits that the teeth and bones of the Megatherium, Mylodon, and other gigantic animals of the Sloth tribe, Armadillo, Mastodon, Horse, &c. are imbedded.*

28. THE SLOTH TRIBE. — The most remarkable of the fossil bones discovered in the Pampas, belong to several extinct colossal animals of the *Edentata;*† an order, of which the Armadillos, Sloths, and Ant-eaters are the living representatives. But as the extinct forms differ greatly from the existing ones, in their gigantic proportions, short massy extremities, and thick and strong tail, their mode of life must have been very dissimilar. To impart a clear perception of the peculiar modification of structure which these extinct beings present, it will be necessary to offer some remarks on the existing types—the Sloths.

The Sloths are arranged by naturalists in a tribe termed *tardigrada*, from their feeble power of progression on the surface of the land; for the same reason they are called *Paresseux* by the French, whence the English name, *Sloth*. They are of slender form and small size : the largest species is but little larger than a cat. They have long toes, and nails which fold up, so as to enable the animal to walk, in the same way as if our fingers were folded under the palms

* Mr. Darwin, Appendix to Beechey's Voyage.

† So named from having no teeth in the front of the jaws.

of the hands; but which are not capable of being retracted into a sheath, as in the feline tribes. The arms are double the length of the legs, and, from the construction of the limbs, the animal, when it walks, or rather crawls on the ground, is obliged to drag itself along on its elbows. But these creatures are destined to inhabit trees; their proper element is on the branches, and they can pass from bough to bough, and from tree to tree, with a rapidity which soon enables them to lose themselves in the depths of the forests. They live on the leaves and the young shoots, and unless disturbed, never quit a tree till they have stripped off every leaf. To avoid the labour of a descent, they drop to the ground, previously coiling themselves into a round ball, in which state, while attached to the branch, they may be taken alive. Thus the habits and economy of the sloth point out the necessity for a peculiarity in the structure of its claws. The monkey leaps and swings himself from tree to tree, and catches at will the branches or the trunk; but the sloths do not grasp; their claws are mere hooks to hang by, and their great strength is in their arms. They never unfix one set of hooks until they have caught a secure hold with the other, thus hanging by their arms and legs, while their bodies are pendant; and they sleep in the same position. The bones of the arm are constructed to suit these conditions. The humerus has a long internal condyle for the origin of large muscles to move the enormous claws; and there is an opening for the passage of the principal nerves and blood-vessels, to protect them from the pressure to which they would be exposed from the powerful muscular action: and the radius (one of the bones of the fore-arm) is constructed to allow of a free rotatory motion to the limb. In the extinct Sloths a similar conformation is maintained, but somewhat modified to suit the different physical conditions under which they existed. There are three genera well established from the fossil remains: the names assigned to them refer to some striking character; as *Megalonyx*, from the enormous size of the claw:—*Megatherium*, or enormous wild animal, from its colossal proportions:—*Mylodon*, or molar-tooth animal, from the peculiarity of its dental organs.

29. THE MEGATHERIUM.—This creature was seven feet high, and nine long, and therefore larger than the largest rhinoceros; but this comparison by no means conveys a proper idea of its bulk, since its proportions are perfectly colossal, the thigh-bone being three times as large as that of the elephant, and the pelvis, or haunch-bone, twice the breadth. It possessed no incisor teeth, and the grinders, which are seven inches long, are of a prismatic form, and, like those of the Sloth, composed of dentine and cement.* They are so formed, that the crown always presents two cutting, wedge-shaped, salient angles. As in an adze, a plate of steel is placed between two of iron, so as to project in a line, in like manner these teeth have in the centre a cylinder of ivory, which is protected by a plate of denser structure, and an external coating of cement; they are, therefore, admirably adapted for cutting and bruising vegetable substances. The entire fore-foot is about a yard in length, and armed with strong claws. The pelvis measures five feet in width, and the sacral aperture of the spinal marrow is one foot in circumference! This enormous size was suitable to the habits of an animal requiring to maintain an upright posture for a considerable time, while employing its fore feet in digging up roots, or in severing and pulling down the young trees and branches, which doubtless constituted the food of this colossal creature.

The *Megatherium* was intermediate between the Sloths, Armadillos, and Ant-eaters; for while in its skull and

* See Professor Owen's "Odontography," vol. i. p. 338.

shoulders it resembled the former, its legs and feet presented an admixture of the characters of the latter.

30. THE MYLODON.—This creature was nearly as large as the Hippopotamus, but shorter. Its hinder extremities are relatively short, and the feet are placed at right angles with the legs, and are as long as the thigh-bones. The tail is remarkably thick and strong, and as long as the hinder extremities. The pelvis is very massive and solid. The ribs are as stout and broad as in the elephant. The fore-legs, or arms, are connected to the sternum by powerful clavicles, and are so constructed as to admit of unrestrained motion in every direction. The toes are five in number on each fore foot, and four on the hinder; the two external toes are unarmed, the others have powerful curved nails or claws. This creature had claws and hoofs on the same foot, and therefore connects the two great groups of recent animals, the *ungulata* and *unguiculata.*

The skull is long, narrow, and smaller than that of the ox; it terminates in a flat or truncated muzzle. The bones of the upper part of the cranium are of enormous thickness, large air-cells being interposed between the inner and outer table. The teeth, which are implanted in very deep sockets, are of the same form and size throughout, and closely resemble in structure those of the Megatherium, but the surface of the crown when worn is flat; there are four on each side in the lower, and five in the upper jaw.*

There is a magnificent skeleton of this creature in the Hunterian Museum; it is as perfect as if the animal had recently been buried, and the bones dug up entire. It is eleven feet long, from the muzzle to the extremity of the tail.†

* See Medals of Creation, vol. ii. pp. 845—847.

† See a Memoir on the "Skeleton of an extinct gigantic Sloth (*Mylodon robustus*)," by Professor Owen. 1 vol. 4to. with plates. 1842.

The Mylodon, like the Megatherium, was a vegetable feeder, and probably browsed on the shrubs and branches of trees. The arms are especially adapted for grasping and wrenching; and though no trees could support the weight of this enormous creature, there is nothing to forbid the supposition that with its hinder feet it could clasp the trunk of a large tree, and with its fore feet climb to a sufficient height to seize and wrench off the branches.

31. The Megalonyx.—An enormous curved ungueal phalanx or claw-bone, and several bones of the arm and sternum, of an animal related to the Sloths, were found many years since in Big-bone Cave, one of the numerous saltpetre caverns which occur in the states of Kentucky, Tennessee, and Virginia. Some of these caves extend many miles under ground, passing beneath hills, valleys, and even rivers. In these subterranean retreats are sometimes found Indian mummies, which are simply desiccated human bodies, in a fine state of preservation; bones of existing species of mammalia, and of mastodons, mammoths, and rarely, of extinct gigantic sloths, also occur.*

The remains of the Megalonyx were first described by President Jefferson; and the claw-bones, the largest of which was nearly seven inches long, excited especial attention, from the supposition that they belonged to a carnivorous animal of marvellous size. But Cuvier, in an admirable memoir, proved that they were referable to an extinct form of the Edentata. I will endeavour briefly to explain how this beautiful induction was established.

The paws both of the canine and feline tribes are armed with claws; in the former the nails are thick and coarse, as in the dog, wolf, &c., and will bear the friction and pressure

* See Dr. Harlan's Medical and Physical Researches, 1 vol. 8vo. Philadelphia, 1845: p. 319.

incident to a long chase; but in the cat tribe, they are curved and sharp, and these qualities are preserved by a particular mechanism. The last bone which supports the claw is placed laterally to the penultimate bone of the phalanx, and is so joined to it, that an elastic ligament draws it back, and raises the sharp extremity of the claw upwards; and the proximal, or nearest extremity of the farthest bone, presses the ground in the ordinary running of the animal, while the claw is retracted into a sheath: but when the creature makes a spring and strikes, the claws are uncased by the action of the flexors or bending tendons. In the Bengal tiger, the claws are so sharp and strong, and the arms so powerful, that they have been known to fracture the skull of a man, by a single touch from the animal in the act of leaping over him. A cat affords a familiar illustration of this peculiarity of structure; when pleased, its claws are retracted, and when angry they are thrown out.

In the claw of the Megalonyx there is no such lateral provision for its retraction, and the point could not have been raised vertically, as in the cat, so as to have permitted it to touch the ground without injury. The articulating surface is double, that is, there is a ridge or spine in the middle, and it must, therefore, have moved like a hinge. The bones of the arm present a corresponding configuration with those of the sloth; the humerus is perforated for the passage of the blood vessels, and the radius is constructed for rotation.

The Megalonyx resembled the Megatherium in its general character, configuration, and habits, but was one-third smaller than that gigantic creature.*

* Casts of all the bones and teeth of the Megalonyx that are in the Museum of Philadelphia, were presented to me by Dr. S. G. Morton of that city, and are now in the British Museum, in the same case with the models of the bones of the Megatherium.

32. The Glyptodon,—so named from the deeply-grooved teeth,—was an animal allied to the armadillos, and possessed a carapace, or coat of mail, formed of polygonal bony plates united by suture, which constituted an impenetrable covering over the upper part of the body. The plates of this bony integument were not disposed in rings as in the armadillo, but were articulated to each other, and formed a tesselated cylinder, or rather arch; the tail was inclosed in a case of this kind, like a sword in its scabbard.*

Such were the gigantic Edentata that inhabited the dry land of South America at a comparatively modern period; and it is worthy of especial remark, that though these beings have long been extinct, sloths, ant-eaters, and armadillos, but of diminutive size, are still the characteristic animals of that country.

33. The Toxodon.—The bones of several other extinct quadrupeds have been found with the relics of the gigantic sloths and armadillos. Among these are the skull and teeth of an animal of large size, named by Professor Owen, *Toxodon*, from the singularly curved form of its molar teeth. The skull is twenty-eight inches long, and sixteen broad, and presents a blending of the osteological characters of the several natural orders of the rodentia, ruminantia, and cetacea.

The Macrauchenia, another extinct pachyderm, found in Patagonia, unites in a remarkable degree the structure of the Camel and Tapir; it must have somewhat resembled the Llama, but had a neck surpassing in length that of any other animal, except the Giraffe.†

34. Fossil hippopotamus, rhinoceros, horse, &c.—With the remains of the mammoth, elephant, and other

* A splendid specimen of the bony cuirass of the Glyptodon is in the Museum of the College of Surgeons.

† An elaborate account of the extinct animals of South America, by Professor Owen, will be found in the "Natural History of the Voyage of the Beagle," by Mr. Darwin.

large mammalia, teeth and bones of several species of hippopotamus, horse, elk, ox, and auroch, are very commonly associated in the alluvial deposits of Europe. In the Vale of Arno, in Italy, immense quantities of the teeth and bones of hippopotami are found ; on the table before us are specimens from that locality ; as well as molars and incisors of a young animal from Huntingdonshire ; and tusks, teeth, and bones, dug up in alluvial marl, at Southbourn, in Sussex. Among the fossils sent me by Major Cautley, from India, are several fine portions of jaws, with teeth, belonging to another species, the *H. Sivaliensis.* Several extinct species have been determined by Baron Cuvier, one of which was not more than half the size of the common Hippopotamus.

The bones and teeth of the Rhinoceros are frequently associated with those of the fossil elephant ; and in this country they occur in superficial gravel and loam. I have obtained specimens from a bed of gravel, on Petteridge Common, in Surrey ; and from loam at the *Wish*, near Southbourn, in Sussex.

The most extraordinary and interesting fact, relating to the Rhinoceros in a fossil state, is the discovery of the entire carcass, covered with its skin, in frozen sand, on the banks of the Wilaji, in Siberia, as previously mentioned (p. 152). The head was extremely large, and sustained two very long horns ; it had no incisors ; the body and limbs were covered with brown hair ; the general form of the animal was lower and more compact than the living species.

The teeth and bones of one or more species of Horse, occur very constantly with those of the other large extinct pachyderms. In these examples of the conglomerated shingle from Brighton cliffs (see p. 114), the coffin, pastern, and cannon bones, as they are termed, of a small species, about the size of a Shetland pony, are imbedded ; in some instances the cavities of the long bones are filled with crystallized carbonate of lime.

In addition to those already mentioned, the deposits now under examination, contain vestiges of other lost forms of mammalia. The fossil remains of an animal resembling the Musk-ox were found with elephants' bones in Siberia; of an extinct species of Fallow-deer in Scania; of Roe-buck and Reindeer* in France; and of gigantic Oxen, Aurochs,† Deer, &c. in our own country. It is worthy of remark, that the fossil pachyderms, such as the elephant, rhinoceros, &c. belong to genera which are now restricted to torrid climes, while the ruminants resemble those which at the present time are natives of northern latitudes.

35. THE DINOTHERIUM.‡—I shall conclude this notice of the fossil mammalia, with an account of a gigantic creature, whose bones occur with those of the mastodon, elephant, and the other terrestrial quadrupeds, previously described.

In various parts of the south of France large molar teeth, resembling in form and structure those of tapirs, have occasionally been found; they are described by Cuvier under the name of the "*Gigantic Tapir.*" Subsequent discoveries in Bavaria, Austria, and particularly at Eppelsheim, about twelve leagues south of Mayence, have thrown light on the osteology of the original, which appears to have been an aquatic animal of great size. The most extraordinary deviation from ordinary types

* In the alluvial loam filling up fissures in the tertiary limestone, at Binstead, Isle of Wight, I discovered the skull of a reindeer, in 1846. See my Geology of the Isle of Wight, p. 104.

† The Auroch is a species of wild bull or buffalo, distinct from the common ox. The horns of the fossil ox are sometimes of enormous size: Mr. Parkinson had a pair in which the length of each horn was 2 feet 7 inches.

‡ *Dinos*, terrible; *therion*, a wild beast.

consists in a pair of curved tusks, which are fixed in the lower jaw, and directed downwards. From the structure of the anterior portion of the cranium, and the disposition of the nasal fossæ, it is supposed that the creature had a proboscis; it possessed no incisor teeth with which to seize its food, and the jaws could not even close together in front; the lower jaw is four feet in length. The tusks resemble

LIGN. 27.—RESTORED FIGURE OF THE DINOTHERIUM.

those of the Walrus, and were probably weapons of defence. This drawing, (*Lign.* 27,) from a restoration by M. Kaup, an eminent German naturalist, to whose researches we are indebted for the important discoveries at Eppelsheim, represents the supposed form of the original creature. It has been assumed that the Dinotherium was nearly related to the hippopotamus, and formed a link between the cetacea and pachyderms; but it seems more probable that it was an herbivorous cetacean related to the Lamantins.

36. FOSSIL CARNIVORA IN CAVERNS.—We have now briefly reviewed the extinct population of a remote period of our globe,—those enormous terrestrial mammalia, the mastodons, mammoths, &c., that lie buried in the alluvial and superficial strata. We pass to the consideration of

a phenomenon not less interesting—the occurrence of immense quantities of bones of many species of carnivora in fissures and caverns. In the former discourse I alluded to the chasms which occur in certain limestone rocks, and described the process by which their roofs, floors, and walls become lined with stalactites and stalagmites (p. 78). Some of these hollows have evidently been occasioned by the destruction of the softer portions of the rock, by the erosion of subterranean streams and rivers: others are so extensive, and present such decided marks of angular fracture, as to leave no doubt that they are rents produced by earthquakes. The occurrence of bones of land animals in such chasms might reasonably be expected.

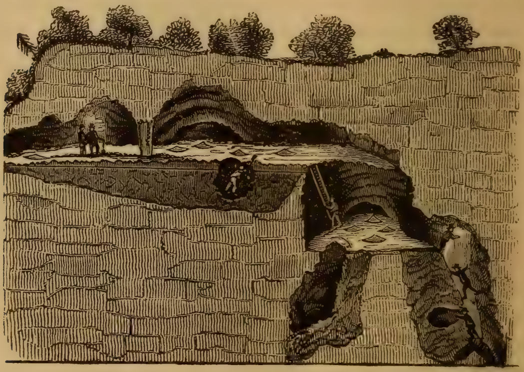
The caves that admitted of easy access from without, and which contain large quantities of bones of but a few species of carnivora, may for a while have been tenanted by species whose habits lead them to retire into secret recesses; and if there were open fissures, kids, deer, &c. may have fallen in, and their bones have become enveloped in calcareous incrustations. But the bones and teeth of herbivora and carnivora, that are promiscuously intermingled in loam and clay at the bottom of fissures and caves, have evidently been drifted in, while the land was under water.

37. Cave of Gaylenreuth.—For many centuries, certain caverns in Germany have been celebrated for their osseous treasures, particularly those in Franconia: the most remarkable is that of Gaylenreuth, which lies to the north-west of the village, on the left bank of the river Wiesent.* The entrance (*Lign.* 28, *a*), which is about seven feet high, is in the face of a perpendicular rock, and leads to a series of chambers from fifteen to twenty feet high,

* See Medals of Creation, vol. ii. p. 869, for an interesting account of the present state of some of these caves, by my friend Major Willoughby Montagu.

and several hundred feet in extent, terminating in a deep chasm (*b*), which, however, has not escaped the ravages of visitors. This cavern is perfectly dark, and the icicles, and pillars of stalactite, reflected by the torches which it is necessary to use, present a highly picturesque effect. The floor is literally paved with bones and fossil teeth ; and the pillars and corbels of stalactite also contain osseous remains.

a



b

LIGN. 28.—VERTICAL SECTION OF THE CAVE OF GAYLENREUTH.
a, The entrance of the cave ; *b*, one of the deep recesses.

A graphic description of this cave was published by M. Esper, in the middle of the last century ; at that period, the innermost recesses contained waggon loads of bones and teeth ; some imbedded in the rock, and others in the loose earth.

The bones are in general scattered and broken, but not rolled ; they are lighter and less solid than recent bones, and are often incrusted with stalactite. Through the kindness of the Earl of Enniskillen, and Sir P. M. de G.

Egerton, I am able to illustrate these remarks by an extensive suite of specimens, exhumed from the deepest recess in the cavern, by these distinguished geologists. But the most interesting relic in my possession is a remarkably perfect skull of a bear, which belonged to my late friend Mr. Parkinson, the author of that delightful work, "*The Organic Remains of a Former World.*"*

Cuvier, who examined a very large collection of bones from Gaylenreuth, determined that at least three-fourths of the osseous contents of the caverns belonged to bears; and the remaining portion to hyenas, tigers, wolves, foxes, gluttons, weasels, and other small carnivora. Most of the bones which are referable to bears, belong to two extinct species. The largest has the skull more prominent in front than any living species, and is called *Ursus spelæus*, or bear of the caverns; the other has a flat forehead, and is named *Ursus priscus*. The Hyena was allied to the spotted hyena of the Cape, but differed in the form of its teeth and head. Bones of the elephant and rhinoceros are also said to have been discovered, together with those of existing animals, and fragments of sepulchral urns of high antiquity.†

38. FÖRSTERSHÖHLE (*Forest Cavern*). — This cavern, which is situated in the same part of Germany, is remarkable for the beauty of its stalactites and sparry incrustations; it varies in height from ten to thirty feet, and its greatest width is about ten yards. In the side vaults or recesses, which descend, at an angle of about forty-five degrees, into the main chamber, the stalagmite has formed the appearance

* Their Royal Highnesses the Princes George of Cumberland and Cambridge, when inspecting my collection at Lewes, a few years since, pointed out the skull and bones of the Ursus spelæus as resembling some fossils that had been exhumed from a fissure in limestone, in the kingdom of Hanover.

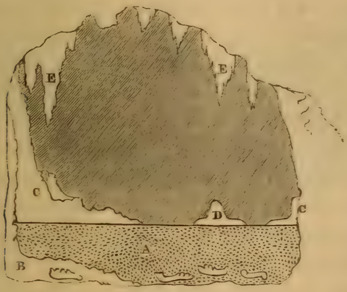
† See Medals of Creation, vol. ii. p. 853, for further details relating to the fossil carnivora.

of cascades of pure alabaster, the waves of which seem to be rushing out at the bottom, to pour themselves into the stagnant lake of the same substance which covers the floor. The roof has been corroded into deep cavities, which are separated by partitions of every conceivable form and tenuity, giving it the appearance of the richly fretted gothic roof of a chapel, with pendent corbels. Beautiful stalactites depending from these projections, reach almost to the floor, and contribute by their delicacy and transparency to throw additional richness over the scene.

It is certainly, as M. Cuvier remarks, a most extraordinary fact, that caves, spread over an extent of two hundred leagues, should have the same osseous contents. The relative proportions of the different species are computed to be as follow:—three-fourths belong to bears—two-thirds of the remainder to hyenas—and a small number to the tiger or lion, and to the wolf or dog; rolled pebbles of a greyish blue marble are the only extraneous materials found with the bones. The singular assemblage of species whose recent types are widely separated geographically, which some of these caves present, is very remarkable. Thus in one cavern, animals allied to the spotted hyena of the Cape of Good Hope, are associated with the remains of others related to the glutton, which inhabits Lapland; and in another, bones of the rhinoceros with those of the reindeer.

Numerous caves containing osseous remains are scattered over the continents of Europe and America; and in Australia, fossil bones referable to animals of different genera, are found, under similar conditions. In the Brazils there are also numerous ossiferous caverns presenting the same general character. These bones belong, for the most part, to genera which still inhabit South America. It is worthy of especial notice, that the bones of a species of horse occur in these accumulations; for when the Spaniards invaded the country, horses were unknown to the inhabitants, who, upon seeing a Spaniard on horseback, actually supposed that the man and horse were but one animal. At the present time, herds of wild horses, the descendants of those introduced by the Spaniards, are distributed over the vast plains of South America. "It is a marvellous event in the history of animals," observes Mr. Darwin, "that a native kind should have disappeared, and be succeeded in after ages by countless herds introduced by the agency of man."*

39. Bone caverns in England.—In England, caves and fissures containing bones of bears, wolves, and other carnivora, in every respect analogous to those of Germany



4 *feet.*

Lign. 29.—Section of the entrance to Kirkdale cave.

(From Dr. Buckland's Reliq. Diluv.)

A. Mud covering the floor of the cave to the depth of one foot, and concealing the bones.
B. Stalagmite containing bones, formed before the mud was introduced.
C. C. Stalagmite formed over the mud.
D. Insulated stalagmite on the surface of the mud.
E. E. Stalactites dependent from the roof.

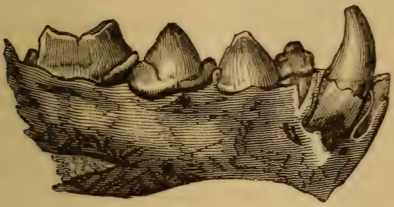
above described, have been discovered and explored. The Dean of Westminster, in his beautiful work, the *Reliquiæ Diluvianæ*, has noticed several of the most important

* Voyage of the Adventure and Beagle.

assemblages of this kind; of these the cave of Kirkdale, in consequence of the highly interesting disquisition on its contents by Dr. Buckland, is the most celebrated.

In the summer of 1821, a deep fissure or chasm was discovered near Kirkdale, about twenty-five miles NN.E. of York, in a bank about sixty feet above the level of a small valley, and near a public road. Some workmen who were quarrying stone, cut across the narrow mouth of a chasm which had been choked up with rubbish, and overgrown with grass and bushes; and which, from this cause, as well as from its inaccessible situation, had hitherto escaped observation. The entrance was so small that a person could only enter in a bent position; and the passage was exceedingly irregular in its dimensions, varying from two to seven feet in breadth, and from two to fourteen feet in height, its greatest length being 245 feet. The cave was divided into several smaller cavities, which were nearly closed by sparry concretions; these occurred where the roof was intersected by fissures, and continued for a few feet, but were gradually lost in the superincumbent limestone; they were thickly lined with stalactites. The true floor was only seen near the entrance, for in the interior the whole was covered with a bed of hardened mud or clay, about a foot in average thickness. The surface was perfectly smooth and level when the cave was first opened, except where stalagmites had formed upon it by infiltration from the roof. Where stalactitic matter incrusted the sides, it also extended over the bottom like a thin coat of ice; and therefore must have been deposited since the mud was introduced. This mud or clay was filled with fragments of bones belonging to a great variety of animals; and some of the bones exhibited marks of having been gnawed. From many corroborative circumstances these appearances were supposed, by the distinguished author, to have been occasioned by hyenas. The bones thus preyed upon belong to the tiger, bear, wolf, fox, weasel, elephant, rhinoceros, hippopotamus, horse, ox, and deer. Bones of a species of hare or rabbit, water-rat, and mouse, with fragments of the skeletons of ravens, pigeons, larks, and ducks, were imbedded with these remains.

From these facts Dr. Buckland inferred that the cave had been inhabited by hyenas for a considerable period, and that many of the remains found there, were of species which had been carried in, and devoured by those animals, and that in some instances the hyenas preyed upon each other;



LIGN. 30.—THE LEFT SIDE OF THE LOWER JAW OF A HYENA, FROM KIRKDALE CAVE.

the gnawed portions of elephants' bones seem to show that occasionally the large mammalia also served as food. It is probable that many of the smaller animals were drifted in by currents, or fell into the chasm, through fissures now closed up by stalactitical incrustations.

KENT'S CAVE, near Torquay in Devonshire, Oreston Cave near Plymouth, and Banwell Cave in the Mendip Hills, are well known for the abundance and variety of the fossil bones imbedded in alluvial drift, with which they are partly filled.*

* In the south-east of England but one instance is known; a fissure in the sand-rock at Boughton Quarries, near Maidstone, contained the jaw and some bones of a hyena, which are now in the Museum at Oxford.

Of these, the first named has been the most productive in objects of interest; probably from the diligent research carried on for many years by several local collectors. A very fine and extensive series obtained by the late Rev. J. MacEnery, of Torquay, is now in the British Museum. It comprises skulls and bones of all the species of carnivora usually met with in such recesses; and also the skull and teeth of a species of Badger, Otter, Pole-cat, Ermine, &c. Among these are a most remarkable canine tooth, six inches long, and an incisor, of a feline animal larger than the Tiger (*Machairodus latidens*); the edges of these teeth are serrated, and the canine is very like in form the tooth of one of the Wealden reptiles (the Megalosaurus). The teeth of another species occur in the caves of Germany; and a skull with teeth, has lately been found in Auvergne. This extraordinary animal was originally named *Ursus cultridens* by Cuvier, who supposed it to have been an extinct species of Bear.*

But this cave is invested with additional interest on another account, which I will here briefly explain. The principal fissure extends 600 feet in length, and there are several lesser lateral ones. The lower part of the cave is filled up to a thickness of 20 feet, with reddish sandy loam full of fossil bones. This is covered by a layer of stalagmite, from one to four feet thick, which forms the floor of the cave. Upon this is a slight covering of earthy matter, with here and there patches of charcoal; a few human bones, and fragments of coarse ancient pottery, have been observed. Upon breaking through the sparry floor the ossiferous earth is exposed; and, *imbedded with the fossil bones*, several flint knives, arrow and spear heads, have been discovered. These stone instruments are of the same kind as those found in the tumuli of the early British tribes, and unquestionably belong to the same period. This fact has given rise to much curious speculation, but the arguments I shall presently bring forward, when speaking of a similar collocation of works of art, and human bones, with those of the extinct cavern animals, will, I conceive, show that the data hitherto obtained, do not warrant the inference, that these relics were contemporary. Kent's Hole, Banwell Cave, and all the ossiferous caves I have examined in England, appear to have been mere rents or fissures in limestone rocks, which were filled with drift, while submerged in shallow water; and the carcases of land animals may have been floated in by the subaqueous currents. As the bones, though broken, are rarely waterworn, and the fragments even retain their sharp edges, the bones must have been more or less protected by

* See British Fossil Mammalia, p. 174.

muscles and skin: the extreme freshness of many of them (especially in Banwell Cave) supports this opinion. Upon the elevation of the land, these fissures were raised above the water, and gradually drained, during which period the formation of stalactite commenced from the percolation of water through the superincumbent beds of limestone. When Kent's Cave was accessible, and before the formation of the floor of stalagmite, some of the wandering tribes of the early Britons may have prowled into the recess, or occasionally sought shelter there; and stone implements, bones, or any hard substances, left in the cave, would soon sink a few feet in the soft ossiferous mud, and become hermetically sealed up, as it were, by the stalagmitic deposit.

From what has been stated, we learn that our wastes and forests were once inhabited by extinct herbivora and carnivora, belonging to genera of which the recent species are almost entirely restricted to southern climates; that some of the caves were tenanted by successive generations of bears, wolves, &c.; that the hyenas, according to their peculiar habits, dragged into their dens the creatures which they killed or found dead, and devoured them at their leisure;—that subsequently all these races were annihilated except the few allied species which still inhabit the European continent and islands. In England, the only living representatives of the three families of carnivora which swarmed in these latitudes during the Mammoth period, are the *Fox*, of the dog tribe; the *Wild Cat*, of the feline order; and the *Badger*, of the bear tribe.*

40. DISEASED BONES OF CARNIVORA FOUND IN CAVES.—Among the bones found in the caves of Germany are many in a condition which must have resulted from accident or disease. In some there has been a formation of new bony matter to repair fractures; in others there is anchylosis, or adhesion of the joints from inflammation: while in some the effects of caries, or decay of the bones, the result of tedious and painful diseases, are apparent. Others have a

* British Fossil Mammalia.

light and spongy character, and are very fragile, which must have arisen from a want of energy in the nutritive system, in consequence of a scrofulous affection.*

41. HUMAN BONES, AND WORKS OF ART IN CAVERNS.—Not only in the caverns of England, but also in those of France and Germany, human bones, and fragments of ancient pottery, have been found. As mankind, in an uncivilized state, commonly inhabit caves, traces of their having occupied recesses, which had previously been the retreat of wild animals, might be expected. But as bones of extinct species occurred with these relics of man, it was assumed that they were coeval with each other; more accurate observations have, however, rendered it probable that the human remains were introduced at a later period. We have historical proof that the early inhabitants of Europe often resided, or sought shelter in caves. Thus Florus records, that Cæsar ordered the inhabitants of Aquitania to be inclosed and suffocated in the caverns to which they had fled for safety.† Many tribes of the Celtic race occupied these subterranean retreats, not only as a refuge in time of war, but also for shelter from cold, and as magazines for their corn, and for the produce of the chase, and as places of concealment for the animals they had domesticated. The bones of such of these people as perished, or were buried in the caverns, would become blended with the mud, gravel, and debris of the animals already entombed; and a stalagmitic paste might in some places be formed by the infiltration of water, as at Bize, and cement the whole into a solid aggregate. In concretionary masses of stone of this kind, containing bones of the bear, and

* Professor Walther, on the antiquity of diseases of bones; see Professor Jameson's Cuvier's Theory of the Earth. Edin. 1827.

† A horrible and atrocious cruelty, which the French, of the nineteenth century, have not scrupled to perpetrate in Algeria!

other extinct species, human bones, fragments of pottery, terrestrial shells, and bones of animals of modern times, may therefore be associated.* Such are the contents of numerous caves, and this explanation shows how they may have been accumulated.†

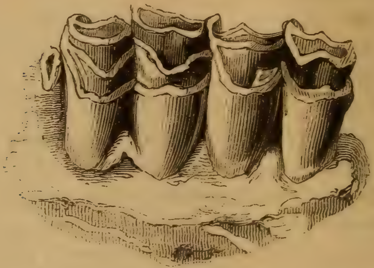
42. Osseous breccia, or bone-conglomerate.—The facts we shall next examine are even more extraordinary than those already described; for the fossil remains are not imbedded in gravel or clay, or collected together in caves, but occur in fissures of limestone, over an area of many hundred leagues, and in rocks and islands very remote from each other. The limestone presents but little variety, the substance in which the fossils are enveloped is everywhere the same, and the bones belong, with few exceptions, to similar species of animals. The rocks in which they occur have been shattered in every direction, and the fissures are filled, more or less completely, with what geologists term an osseous or bone-breccia; that is, an aggregation of bones held together by a calcareous cement or paste, in the same manner as the conglomerated shingle near Brighton (p. 79); or, to exemplify its nature by a still more familiar illustration, the mixture of mortar, pebbles, &c. which is employed in masonry, and called concrete.

This cement is of a reddish brown colour, and much resembles common brick, while the bones are beautifully white, and in many instances have their cavities lined with spar. In some examples the bones have undergone but little change; in others, the cells of the cancellated structure are filled with calcareous matter. The specimen before us

* Memoir by M. Desnoyer.

† The femur of the Bear is so like the human thigh-bone, as to be readily mistaken, without due caution; see Prof. Owen; British Mammalia, p. 96: in which the distinctive characters of each are pointed out.

(*Lign.* 31) is from Gibraltar, and contains two teeth, and fragments of bone, of a ruminant. The breccia in which the teeth are imbedded is now a compact limestone; it is of a



LIGN. 31.—TEETH OF A RUMINANT IN OSSEOUS BRECCIA, FROM GIBRALTAR.

dull red colour, mottled with white, and susceptible of a good polish. This osseous breccia occurs on the northern shores of the Mediterranean; in the rock of Gibraltar; at Cette, Nice, and Antibes; in Dalmatia, and in the isles of Cerigo, Corsica, &c.; and in Sicily, Sardinia, and many parts of Germany. Each of these localities presents highly interesting examples of the objects of our present inquiry.

43. THE ROCK OF GIBRALTER.—As the rock of Gibraltar, so well known from its historical and political importance, affords a good illustration of the phenomena under review, I shall, for the sake of brevity, confine my observations to that celebrated spot. Gibraltar is situated on the Spanish side of the Mediterranean, being united to the main land by a narrow isthmus, which is a mere bank of consolidated sand, about three-fourths of a mile broad, and only eight or ten feet above the level of the sea. The rock stands on the western extremity of the area in which the osseous breccia occurs, and its greatest altitude is about 1,350

feet. It is in great part composed of strata of compact, bluish-grey marble, of the oolitic period, which like most extensive limestone masses is cavernous. The principal cavern, called St. Michael's, contains stalagmites and stalactites, which when polished are of great beauty. The fissures intersecting the rock, as well as those in some of the caves, are partially filled up with a calcareous concretion, of a reddish-brown colour, which in some parts is a mere earthy mass, but in others is highly indurated. The bones are commonly in a broken state, and but seldom water-worn; and the fragments of limestone with which the fissures abound, are also angular, and have evidently, like the bones, fallen into the crevices at different periods, and been gradually incrusted and conglomerated by calcareous infiltrations. Snails and other land shells of the existing species of the country often occur impacted in the solid breccia; and as the stalactitic concretion is constantly going on, some masses contain recent terrestrial shells unmixed with bones.

The cementing material is very similar in the different localities where the breccia has been observed; namely, at Cette, Nice, Antibes, &c. in Dalmatia and Sardinia. The animal remains of the breccia are referable to several species, some of which are recent and others probably extinct, of deer, antelope, rabbit, rat, mouse, &c. Bones of birds and of lizards have been discovered at Cette; and of lemmings,* and of the *lagomys*,† which now only exists in Siberia: it is but rarely that traces of carnivora are observed.‡

No one can fail being struck with surprise at the occurrence of these isolated, yet analogous phenomena, which

* Lapland marmot.

† Signifying rat, or tailless hare; a small animal which forms a link between the hare and the rat.

‡ See an interesting memoir in the Geology of the Environs of Nice, by Sir H. De la Beche: Geol. Trans. vol. iii. p. 171.

surround the great basin of the Mediterranean;—rocks of a uniform character, fissured and broken, their rents filled up with similar materials, and with the remains of the same species of animals. The occurrence of species, either extinct, or no longer inhabiting the same latitudes (as the *lagomys*), refers the period of the existence of these animals to the epoch of the mammoths and mastodons; and the absence of marine remains, and of the usual abrading effects of water, show that the breccia was formed on dry land, and not beneath the sea. The rational explanation of these facts, appears to be that which assumes the original union of these distant rocks and islands into a continent, or large island, that, like Calabria, was subject to repeated visitations of earthquakes; and that the animals which inhabited the country fell into the fissures thus produced, and were preserved by the calcareous infiltrations that were constantly in progress. Subsequent convulsions severed the country into rocks and insular masses, of which catastrophes the osseous conglomerates are the physical and only records.

44. Osseous breccia of Australia.—Caves and fissures, filled with osseous breccia, of the same nature as that above described, have also been discovered in New Holland, to the westward of Sydney, near the banks of the Macquarrie river; and it is not a little remarkable, that even the red ochreous colour of the European conglomerates prevails; the bones, however, belong to animals wholly distinct from any noticed in the preceding examples. Some of them are of living, others of extinct species, but almost all are referable to marsupial animals, as the *Kangaroo, Wombat, Dasyurus*, &c. A portion of a large bone, found in a cave, is said to belong to the hippopotamus, and another fragment to the mastodon, but this requires confirmation; it is, however, a subject worthy of attention, since the kangaroo is the largest animal now

known in those regions. The fact that the fossil animals hitherto discovered are marsupial, that is, belong to mammalia which carry their young in a pouch—a type of organization which is the peculiar feature of the existing Australian fauna—is of great interest, for it proves that the present zoological character of the country has prevailed from a very remote period.

45. RETROSPECT.—I must now bring to a close this survey of the ancient superficial deposits—those accumulations of alluvial debris, which, taken as a whole, are referable to a far more remote period than those which strictly belong to the human epoch ; although the ancient pass by insensible gradations into those of comparatively recent origin.

In the former discourse I found it necessary to refer to the discoveries of Astronomy, to elucidate the earliest physical conditions of our planet; in the present I have summoned comparative anatomy to our aid, and have endeavoured to point out the mode of induction pursued by the palæontologist, in his inquiries into the fossil remains of animal organization, and by which he is enabled to call forth from their rocky sepulchres, the beings of past ages, and, like the fabled sorcerer, give form and animation to the inhabitants of the tomb.

From the facts that have been reviewed in the course of this Lecture, the following inferences result.

First—that the extinction of certain forms of animal organization has extended throughout the period comprehended in our present researches. We have traced its influence from the partial extirpation of certain existing forms, to the entire annihilation of many species and genera that once were contemporary with man ; as well as to those which lived, and became extinct, antecedent to all traces of the human race.

Secondly—that while in the modern marine and fluviatile deposits, the remains of existing species of animals, and of man and his works, are entombed,—in the ancient alluvial sediments, those of large extinct mammalia, are chiefly imbedded, and no vestiges of human remains have been discovered.

Thirdly—that the bones principally belong to extinct mammalia, related to the elephant, hippopotamus, sloth, horse, deer, &c.; and to the bear, hyena, tiger, and other carnivora; and with these are associated the remains of recent species.

Fourthly—that in the period immediately antecedent to the present state of the earth's surface, the dry land teemed with large herbivorous animals, which roamed through the primeval forests, unmolested, save by beasts of prey. Numerous species and entire genera have since been swept away from the face of the earth,—some by physical revolutions, others by a gradual decadence,—while many have been exterminated by man.

Lastly—that the various deposits in which these fossils are imbedded, whether formed in the beds of lakes, rivers, or estuaries, have been elevated above the level of the waters and become dry land, at a comparatively recent period, and now constitute fertile countries, supporting busy communities of the human race.

I have thus endeavoured to interpret one chapter in the ancient physical history of our planet, and explain the records of one epoch in geological chronology. We have entered upon the confines of the past, and already we find ourselves surrounded by an innumerable population of unknown types of being,—not as dim and shadowy phantoms of the imagination, but in all the reality of form and structure, and bearing the impress of the mighty changes of which they constitute the imperishable memorials. We have witnessed the effects of repeated changes in the relative level of the land and water,—have seen that our present plains and valleys were submerged beneath the ocean, at a period when large mammalia, apparently unrestricted by existing geographical limits, were inhabitants of regions which are now no more;—and we have obtained additional proof that—

> New worlds are still emerging from the deep,
> The old descending in their turn to rise!

Even in this early stage of our progress, we have conclusive evidence of the extinction of whole tribes of animals, alike admirably adapted to the conditions in which they were placed, as the races which have survived. And it is most gratifying to the geologist to find, that this fact, which but a few years since was received with hesitation by most, and condemned and rejected by many, is now adduced by the moralist and divine, as affording new and striking proofs of the wisdom and overruling providence of the Eternal.*

* See Dr. Buckland's Bridgewater Essay.

LECTURE III.

1. Introductory. 2. Mineral composition of Rocks. 3. Crystallization. 4. Stratification. 5. Displaced Strata. 6. Veins and Faults. 7. Chronological Synopsis of the Strata. 8. Geology of England. 9. Alluvium and Drift of the Modern Epoch. 10. Erratic Boulders. 11. Tertiary Formations. 12. Classification of the Tertiary. 13. Fossil Shells. 14. Lithological Characters of the Tertiary. 15. Subdivisions of the Tertiary System. 16. Pliocene Deposits. 17. Miocene; the Crag. 18. Eocene, or Lower Tertiary. 19. The Paris Basin. 20. The London Basin. 21. The Isle of Sheppey. 22. Bagshot Sand. 23. Phenomena of Springs. 24. Artesian Wells. 25. The Hampshire Basin. 26. Alum Bay. 27. London Clay of Hampshire. 28. Freshwater Tertiary of the Isle of Wight. 29. Organic Remains of the Eocene Strata. 30. Amber. 31. Zoophytes of the Tertiary. 32. Shells of the Tertiary. 33. Fossil Nautilus. 34. Nummulites. 35. Rotaliæ. 36. Crustaceans and Fishes. 37. Tertiary Reptiles. 38. Tertiary Birds. 39. Fossil Mammalia of Paris. 40. Palæotheria and Anoplotheria. 41. Fossil Monkeys. 42. Tertiary Deposits of Aix. 43. Fossil Insects. 44. Fossil Fox of Œningen. 45. Fossil Fishes of Monte Bolca. 46. Tertiary Volcanoes of France. 47. Extinct Volcanoes of Auvergne. 48. Crater of the Puy de Come. 49. Mont Dore. 50. Lacustrine Strata of Auvergne. 51. Successive Epochs of Mammalia. 52. Survey of Geological Phenomena. 53. Excavation of Valleys by running Water. 54. Extinct Volcanoes of the Rhine. 55. Brown Coal Deposits; the Loess. 56. Tertiary of Europe and North America. 57. Altered Tertiary of the Andes. 58. Saliferous Deposits. 59. Retrospect. 60. Concluding Remarks.

1. Introductory.—Although it is my object in these Lectures to present a general view of the philosophy of Geology, and render the examination of geological phenomena subservient to an exposition of the laws which the Divine Author of all things has established for the renovation, maintenance, and government of the organic and inorganic kingdoms of Nature, I must enter somewhat in detail on the nature and distribution of the materials of which the crust of the earth is composed. For based as Geology is upon observations of the various physical changes which are now taking place on the surface of

our globe, and on investigations of the natural records of similar changes in periods antecedent to all human history and tradition, the minerals and fossils are the alphabet, the rocks and mountains the volume, by which the student of this interesting department of science must learn its important lessons. But to those who cannot examine Nature in her secret recesses, or accompany an experienced teacher to the valleys, or the mountain-tops, lectures illustrated by specimens and drawings, afford, perhaps, the best substitute for the more efficient and interesting mode of instruction.

That we may obtain a clear and comprehensive view of the vast field of inquiry that lies before us, artificial classifications are necessary in this, as in other departments of science; and without assuming that the arrangement in which the various deposits are grouped by modern geologists, may not require considerable modification as new facts are brought to light, I will place before you a tabular view of the formations, or systems of deposits, in their presumed chronological order. At the same time it must be borne in mind, that all arrangements of this kind necessarily involve arbitrary distinctions; and that it may, possibly, hereafter appear, that we have in some instances classed as general, what are but local phenomena; and have grouped together in one system, strata, which farther investigations may show to be distinct formations, separated from each other by vast periods of time. It must too be admitted, that there are not in nature those strict lines of demarcation between one system of strata and another, which, for the convenience of study, have been adopted. For though the limits of certain formations may be clearly defined in one region, in other and distant countries there may be an insensible passage from one system to the other. In short, both in the organic and inorganic kingdoms of nature, in proportion as our knowledge is increased, and our views enlarged, the harmony and unity of nature become more and more manifest; the apparent breaks in the chain of causation exist only in our imperfect conceptions. These considerations will not, however, affect those leading principles of Geology which it is my present endeavour to render familiar to the intelligent but unscientific inquirer.

In pursuance of this object we will first take a general view of the nature of the mineral substances which enter into the composition of the crust of the earth, and briefly notice the laws which regulate the deposition of sedimentary detritus in the beds of rivers, and in the depths of the ocean.

2. MINERAL COMPOSITION OF ROCKS.—Every substance is composed of atoms of inconceivable minuteness, held together by a principle termed attraction or cohesion, and which is probably a modification of that influence, which, as it exists under certain conditions in inorganic substances, is called electricity, galvanism, or magnetism; and in organized beings, nervous influence.* The different states of solidity, fluidity, and vapour, in which every material body may exist, were exemplified in a former lecture, and we need only remark, that of the substances, which in the present state of chemical knowledge are considered simple or elementary, about sixteen constitute, in their various combinations, by far the largest amount of all organic and inorganic matter. Of these, eight are non-metallic; viz. *oxygen*, *hydrogen*, *nitrogen*, *carbon*, *sulphur*, *chlorine*, *fluorine*, and *phosphorus;* the four first are almost always found in combination. *Oxygen* constitutes one-fifth part of the atmosphere, and eight-ninths in weight of water, and a large proportion of every kind of rock. *Hydrogen* makes up the remaining portion of water; and *Nitrogen*

* See a masterly "Essay on the Correlation of Physical Forces," by W. B. Grove, Esq. F.R.S. London, 1846.

four-fifths of the atmosphere. *Carbon* is the chief constituent of animal and vegetable structures, and is only found pure in the diamond.

There are also six metallic bases of alkalies and earths; namely, *silicon*, which, when united with an equivalent of oxygen, forms quartz, or flint, the basis of nearly half the rocks that compose the crust of the earth; *aluminum*, *potassium*, *sodium*, *magnesium*, and *calcium;* and two, the oxides of which are neither earths nor alkalies, namely, *iron* and *manganese*. The principal remaining metallic substances, viz. *copper*, *lead*, *zinc*, *arsenic*, *silver*, *gold*, &c. are comparatively unimportant in a geological point of view.

The sedimentary rocks are in a great measure composed either of lime, silex, or argillaceous earth; and accordingly as these substances predominate, the masses possess, what in mineralogical language is called a *cleavage*, or peculiar fracture, which is distinct in each. Thus, if I take this piece of flint and break it at random, it presents a glassy or *conchoidal* fracture, and every fragment has a sharp cutting edge; and subdivide it as I may, each portion retains the same character: but if I break this block of chalk, the edge is not sharp, but blunt and dull, exhibiting what is termed an *earthy* fracture. Again, if I shiver to pieces by a blow of a hammer this calcareous spar, every fragment partakes, more or less distinctly, of a rhomboidal form; so true is the remark, that we cannot break a stone but in nature's joinings.

3. Crystallization.—Crystallization may be defined a methodical arrangement of the particles of matter according to fixed laws.* For example—there are nearly 500 varieties

* The definite or mathematical proportions in which substances unite, both as to weight and volume, is a subject of the highest interest, but which does not come within the scope of the present inquiry.

of crystallized carbonate of lime, each crystal being composed of millions of atoms of the same compound substances, and having one invariable primary form—that of a rhomboid. Mechanical division is incapable of altering this arrangement; break the fragments as we may, we can only separate them into a rhomboidal figure; nor can this condition be altered except by chemical decomposition. If we pursue the investigation we find by analysis, that every atom of these crystals consists of lime and carbonic acid, each of which is made up of innumerable molecules. "Lime and carbonic acid are also themselves compounds, lime consisting of a metal called calcium and oxygen; and carbonic acid, of carbon and oxygen. Thus these ultimate particles of calcium, carbon, and oxygen, form the indivisible atoms into which all the secondary crystals of lime may be reduced." *

4. Stratification.—Having previously shown that the disintegration and solution of the most refractory, and apparently indestructible substances, may take place from the conjoined effects of mechanical and chemical agency, we proceed to the consideration of the manner in which the debris of the ancient lands, and the accumulations in the seas, have been converted into the rocks and strata that form the existing islands and continents. The formation of beach and sand, and the deposition of mud and clay in layers or strata, and the subsequent consolidation of these materials into rocks, have already been explained. And here let me remind you, that *strata* are successive layers of detritus spread over each other in such manner, as to allow of the partial consolidation of one bed, before the deposition of another upon it; and a rock is said to be *stratified*, when it presents the appearance of such divisions. Chalk cliffs, and sandstone and limestone quarries, afford illus-

* Dr. Buckland's Bridgwater Essay.

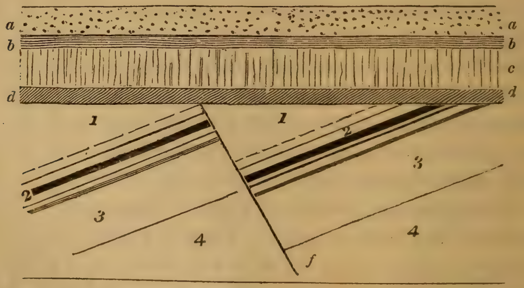
trations of this structure. The original direction of these layers must have been more or less horizontal, for this obvious reason, that in their fluid state they would find their own level, and spread over the surface of the basin into which they flowed; and although they might partake of the inequalities of the depressions in which they were deposited, yet this cause would not affect their general distribution. The strata when accumulated in very thin layers, resembling the seams formed by the leaves of a closed book, are termed *laminæ;* a character that commonly prevails in fluviatile or river deposits: thus the shales, clays, and sandstones, of Tilgate Forest are laminated, and often bear the impress of the waves which have flowed over them (see p. 60).

The contemporaneous beds formed in the same oceanic basin, though often maintaining a general character over very extensive areas, must nevertheless vary considerably. At the present moment, the rivers flowing from different latitudes into the existing seas, must necessarily be producing in the same marine basin accumulations of a very dissimilar character; and the distribution of the detritus, must be greatly modified by the agency of those powerful currents, to which allusion has already been made (p. 70). These elements of variation in the deposits that may be formed contemporaneously within the same ocean bed, serve to explain the origin of similar discrepancies in the contents of the ancient seas. Thus the same system, or formation, may consist of strata containing exclusively marine shells, corals, fishes, &c. intercalated with layers of clays and sands, abounding in lacustrine shells, and plants, and the remains of terrestrial animals and vegetables: the former being strictly of *marine*, and the latter of *fluvio-marine* origin; in other words, consisting of deposits brought into the sea by river currents loaded with the detritus of the land.

The oolitic system of Yorkshire affords examples of these alternations of marine and fluvio-marine strata.

5. DISPLACED STRATA.—But though the sedimentary strata have originally been deposited in horizontal layers, yet this arrangement has subsequently been disturbed by expansive internal forces, which have occasioned the elevation of some areas and the depression of others, by which the strata have been broken up, and thrown into every direction, from a slight degree of inclination, to a vertical position.

It will therefore be requisite in this place to explain a few scientific terms which are frequently employed to express these phenomena; for though it is my wish to abstain as much as possible from technical language, it cannot in all cases be avoided without incurring inconvenient circumlocution. Parallel layers or strata, placed horizontally upon each other, as *a*, *b*, *c*, *d*, in the annexed



LIGN. 32.—ILLUSTRATIVE OF STRATIFICATION.

a, *b*, *c*, *d*, Horizontal strata in a conformable position, resting unconformably on the inclined strata, 1, 2, 3, 4.

1, 2, 3, 4, Strata in an inclined position, and severed and displaced by a fault, *f*.

diagram (*Lign.* 32), are said to be *conformable;* but when strata are superimposed on others which lie in a different direction, as the series *a, b, c, d,* on the beds 1, 2, 3, 4,—as if a set of horizontal volumes were placed flat on the inclined edges of another series of books,—they are termed *unconformable.*

6. Veins and faults.—But the strata have not only suffered change of position, they have also been rent and broken, and are traversed by cracks or fissures, which in some instances are filled with bones, pebbles, and stalactitical concretions (p. 78), and in others with mineral matter, and veins of metalliferous ores. The term *fault* is applied to those fractures and displacements which are accompanied with the subsidence of one part of a mass, and the elevation of another. This is exemplified in the section of the carboniferous strata represented in *Lign.* 32, in which the layers, or seams of coal (1, 2, 3, 4), have been shifted to a higher level on the left hand, though both sides of the rock remain in apposition; *f,* marks the line of fault. Strata, in fact, may be compared with the layers of masonry in a building; beds of clay representing the mortar, and those of harder rocks the courses of brick or stone; while the fissures, veins, and faults, are analogous to the cracks, sinkings, and displacements, produced by the settling of different portions of the edifice after its erection.

7. Chronological arrangement of the strata.—In the alluvial beds of gravel, sand, and marl, containing the remains of the large herbivorous mammalia, which formed the principal subject of the previous discourse, but few indications of regular stratification are observable; the deposits for the most part consisting of materials that have been transported by rivers or currents, or drifted by icebergs, and accumulated in estuaries and bays, or spread along the shallows of sea-coasts. The vast series of ancient deposits we are about to examine, are on the contrary composed of regularly stratified rocks, with occasional

interspersions of fluviatile and alluvial debris, and intrusions of volcanic matter.

It is necessary to premise, that there are three elements of classification applicable to stratified rocks; namely, 1st, their mineral structure; 2dly, their order of superposition; and 3dly, the nature of the organic remains which they contain: the following arrangement is in accordance with these principles. The terms by which the formations and their subdivisions are designated, express the predominant characters by which they are distinguished.

A CHRONOLOGICAL SYNOPSIS OF THE PRINCIPAL ROCKS AND STRATA.

(*Commencing with the uppermost or newest deposits.*)

Fossiliferous Strata.

I. The Human or Modern Epoch.—Alluvium or Drift; comprising the superficial deposits described in the previous Lecture, and which are characterized by the remains of *Man*, and of animals and plants, contemporaneous with the human race.

Observations.—To this epoch belong those superficial accumulations of alluvial debris, and of drifted gravel, sand, boulders, &c., of rocks of all ages, in which, with shells, and bones of existing species of animals, are associated those of the Mammoth, Irish Elk, and other extirpated genera; together with the remains of the more ancient extinct mammalia, that occur in caverns and fissures of various rocks. The line of demarcation between the most ancient beds of this epoch, and the most modern of the following, cannot be strictly defined; and the separation can only be regarded as conventional. In Europe, the elevation of the Alps appears to have been the grand physical event which marked the close of the tertiary period; for in all deposits of later age, existing species have been met with.

II. The Tertiary Epoch.—An extensive series comprising many isolated groups of marine, fluvio-marine, and lacustrine deposits, containing remains of animals and vegetables of all the existing orders and families, and many genera and species; and with these are associated numerous extinct species and genera of mammalia, reptiles, fishes, mollusks, &c.

Observations.—The formations of this epoch are assemblages of marine, fluvio-marine, and lacustrine strata, either isolated or alternating, and occupying extensive but defined areas. These beds consist of detritus, accumulated during long periods, in bays, gulfs, deltas, and lakes, and in the depths of the ocean. Intrusions of lava currents, scoriæ, and other volcanic products, occur in many of the tertiary formations. The zoological character of this period is the prevalence of terrestrial mammalia.

III. THE SECONDARY EPOCH.—An immense series of marine strata, with intercalations of fluvio-marine deposits, and one extensive delta. The most striking zoological characters of this epoch are the almost entire absence of warm-blooded animals, and the abundance of terrestrial and aquatic reptiles. The aggregate thickness of the strata is many thousand feet. The following are the principal subdivisions of the formations comprised in this class.

1. THE CRETACEOUS (or *Chalk*) FORMATION.—Marine strata, with but few interspersions of terrestrial or fluviatile debris. In England, the white limestone, termed Chalk, forms the upper strata; marls and clays the medial; and clays, sands, and sandstones, the lower portion of the series. The strata abound in the remains of extinct species of zoophytes, mollusca, echinoderms, fishes, and reptiles. Drifted wood, and some marine plants are, with but few exceptions, the only vegetable exuviæ.

Observations.—The strata comprehended in the term *Cretaceous Formation,* though differing essentially in their lithological constituents, so far correspond in the nature of their organic remains, as to prove that the whole were formed under the same general conditions; in other words, that the sea and land, and their inhabitants, underwent no essential change during the vast periods in which these deposits were accumulated; the entire series therefore constitutes, in geological language, but one formation. With but a very few exceptions, no vestiges of existing species of animals have been detected.

2. THE WEALDEN FORMATION.—A series of fluviatile deposits of great thickness and extent, with scarcely any interpolations whatever of marine detritus. The lithological characters are, alternations of clays, limestones, sands, and sandstones, with beds of freshwater shells and crustaceans. The peculiar organic features are the abundance of the remains of enormous land and aquatic reptiles, river shells, and crustaceans; and coniferous trees, cycadeous plants, ferns, and other terrestrial vegetables.

Observations.—This remarkable series presents the most unequivocal example of an ancient delta, or assemblage of fluviatile deposits, hitherto observed. The strata exhibit throughout the character of river detritus, that has been accumulated in a vast inland lake, which received the drainage of an extensive country, and had but a restricted communication with the ocean. The Wealden extends over the whole of the south-east of England, and a great part of the north of Germany.

3. THE JURASSIC OR OOLITIC FORMATION.—A formation of great thickness and extent, consisting of several groups of marine limestones and clays, which abound in extinct marine shells, corals, crinoidea, crustaceans, fishes, and reptiles; with intercalations of fluvio-marine strata, in which are remains of terrestrial reptiles, insects, and plants; and of *two genera of small extinct mammalia.* Layers and beds of coal, and lignite, of considerable extent, occur in some parts of the system.

4. THE LIAS.—Marine clays, shales, and limestones full of shells, crinoidea, crustaceans, fishes, and extinct reptiles; with fluvio-marine beds, containing lignite, trunks and leaves of coniferous trees, and cycadeous plants.

Observations.—The Oolite and Lias, though conveniently distinguished by certain species of shells, &c., must be regarded as but one natural series or group of deposits, formed in the bed of an ocean of great extent, into which numerous streams transported the debris of the land, and its inhabitants. Two genera of marine reptiles, *Ichthyosaurus* and *Plesiosaurus,* swarmed in the Liassic and Oolitic ocean, and their remains abound throughout the system.

5. THE TRIASSIC (*New Red*) FORMATION.—A group of variegated, blue, yellow, and red marls, abounding in gypsum and salt; with sandstones, limestones, and conglomerates, for the most part coloured red by peroxide of iron. Fossils are not abundant, but some peculiar shells, corals, crinoidea, reptiles, and coniferous plants, characterize the series, which is of marine formation.

Observations.—This group is the grand depository of rock salt in England. In Germany the strata form a triple series (whence the name *Triassic*) of variegated marls, limestones, and sandstones, which contains peculiar fossil remains. The separation of these deposits from the following has been made in consequence of certain genera and species of animals, which abound in the more ancient rocks, being entirely absent in the Triassic, and all the subsequent formations; and also from some genera, especially of Batrachian and other reptiles, appearing for the first time in strata of this age. The Triassic is therefore, at present, regarded as the lowermost, or base line, of the formations comprised in the secondary epoch; the faunas and floras of the older strata being entirely distinct.

IV. THE PALÆOZOIC EPOCH.—Under this general term are comprised all the ancient fossiliferous strata, the organic remains of which, as the name indicates, belong almost exclusively to species or genera that are wanting in all the newer formations.

6. THE PERMIAN (*Magnesian Limestone*) FORMATION.—A series of marine strata, consisting of limestones charged with a large proportion of magnesia, red marls, conglomerates, and slates. These contain peculiar shells, fishes, and reptiles.

Observations.—This group of deposits was formerly named the *Lower New Red,* or *Magnesian Limestone;* but, as either of these terms is ambiguous, that of Permian (first suggested by Sir R. Murchison, from the large development of the series in the ancient kingdom of Permia in Russia) is now generally adopted. In this group are included all the deposits that intervene between the Triassic above, and the Carboniferous systems below; and these contain but one type of animal and vegetable life. Remains of reptiles occur, and are the most ancient, or earliest, of this class of animals.

7. THE CARBONIFEROUS FORMATION.—Sandstones, grits, shales, clays, and layers of ironstone, alternating with beds of coal, form the upper series;—limestone and flagstone, with layers and nodules of chert, abounding in marine shells, crinoidea, and corals, constitute the lower division of this extensive group of deposits; the total thickness of which is many thousand feet. The coal strata are remarkable for the abundance and peculiarity of the terrestrial trees and plants, of which they are almost wholly constituted; remains of insects, fishes, and crustaceans of an extinct family have been found in this formation.

Observations.—These strata, so interesting to the botanist from the richness and peculiarity of their fossil flora, and to mankind in general for the inexhaustible supply of fuel which they yield, appear for the most part to have been deposited in salt water; for the beds of coal are generally associated with marine shells, corals, &c.; and there are only a few local intercalations of layers of fresh water shells. The flora of the coal is the most striking feature of this system of deposits.

8. THE DEVONIAN *(Old Red)* FORMATION.—An assemblage of quartzose grits, sandstones, marls, and conglomerates, largely charged with peroxide of iron, which imparts to the whole a dull red colour; with beds of coralline marble, and laminated micaceous sandstones; this formation was formerly, from its colour, denominated the Old Red sandstone. Shells, corals, fishes, crustaceans, and cephalopoda, of peculiar species and genera, are the prevailing and characteristic organic remains.

Observations.—The term Devonian, which has been substituted for that of Old Red Sandstone, as being more precise, is derived from the geographical development of this group of rocks in Devonshire, England. The red conglomerates, which constitute a well marked lithological character, consist of water-worn fragments of slate with quartz pebbles, cemented together by red sand and marl, and have evidently resulted from the destruction of ancient slate rocks; they are in many instances mixed up with volcanic ashes and scoriæ. Beautiful coralline marbles occur in South Devonshire, and in some localities fishes of a very remarkable conformation, belonging to genera unknown in any other system.

9. THE SILURIAN FORMATION.—Marine limestones, sandstones, shales, and calcareous flagstones, abounding in shells, cephalopoda, corals, and crustaceans, (especially of the extinct family of Trilobites,) of peculiar types, constitute this important and extensive system of marine deposits. A few traces of fuci are the only known vegetable remains.

Observations.—This system (which was first established by Sir R. Murchison) is entirely of marine origin, and many beds are aggregations of corals, shells, &c. cemented together by calcareous matter. The organic remains are numerous, and afford characters by which the system is conveniently subdivided into two groups; but only one general organic type prevails throughout. The lowermost beds contain but very few fossils, and insensibly pass into sedimentary deposits, in which no traces of organic existence have yet been discovered.

10. THE CUMBRIAN *(Schistose)* FORMATION.—A largely developed series of slate rocks, and conglomerates, several thousand yards in thickness; the uppermost beds contain a few shells and corals, which are not distinguishable from Lower Silurian species.

Observations.—This system includes all the sedimentary deposits between the lowermost of the Silurian and the uppermost of the ancient metamorphic rocks. It has been named by Professor Sedgwick *Cambrian,* and *Cumbrian,* from the large development of the strata in Wales and Cumberland. But as no assemblage of organic remains specifically distinct from the fossils of the Silurian has been detected, a zoological line of separation cannot at present be drawn between the lower Silurian and the Cambrian deposits. Until characteristic fossils be met with, the group, therefore, as a distinct system, rests on the geological position and lithological characters of the strata so largely developed in Cumberland. Future researches will, in all probability, lead to the discovery of peculiar organisms, more ancient than the Silurian types.

Hypogene Rocks.

I. METAMORPHIC ; or stratified crystalline rocks.

Observations.—These rocks are presumed to be sedimentary deposits, that have been metamorphosed or changed in mineral structure from long exposure to a high temperature under great pressure; by which their constituent substances have passed into new combinations, and all traces of any organic remains they may have contained entirely obliterated. The name *Hypogene,* or *nether-formed* rocks, (suggested by Mr. Lyell,*) refers to the condition under which these rocks are supposed to have originated. They are subdivided into two groups:

1. *Mica-schist system;* comprising mica-slate, quartz rock, hornblende-schist, and crystalline limestone.
2. *Gneiss system;* layers of gneiss, quartz rock, syenite, &c., alternating with clay-slate, and mica-schist.

Observations.—The *mica-schist* is a slaty rock, composed of mica and quartz, and often passes insensibly into clay-slate. *Gneiss* is formed of mica, quartz, and felspar, has a laminated structure, and often occurs in distinct layers, or strata.

II. PLUTONIC ; or amorphous crystalline rocks.

Granitic System; comprising *Granite, Porphyry,* and certain Trap rocks.

Observations.—The well known rock, termed granite, which, like gneiss, is composed of mica, quartz, and felspar, is not stratified or disposed in layers, but occurs either in amorphous masses protruded through newer rocks, or in dikes and veins, which often traverse strata of all ages. The traps, porphyries, &c., included in this system, have the character of mineral masses, which have been rendered crystalline by intense fusion, under great pressure, in the depths of the earth.

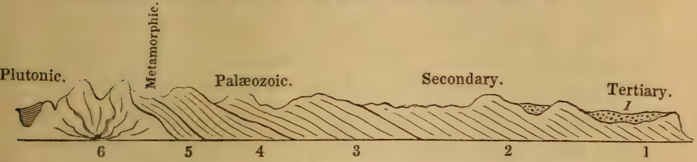
Volcanic Rocks.

1. *Trap, Basalt, Tuff, Toadstone,* and *Obsidian,* or *glassy lava:*—products erupted from ancient volcanoes.

* From ὑπο, *under,* and γινομαι, *to be born;* see "Elements of Geology," p. 20.

2. *Lava, Scoriæ, Pumice, Ashes,* &c. :—products of modern dormant and active sub-aerial volcanoes.

Observations.—In this class are placed the mineral productions of fire, or subterranean heat, ejected from beneath the surface, through fissures or rents, whether in ancient or modern times. These igneous materials are of all ages; they traverse alike the hypogene rocks, and the sedimentary strata, as well as the most recent deposits.



LIGN. 32.*—DIAGRAM OF THE RELATIVE POSITION OF THE ROCKS AND STRATA IN ENGLAND.

1. Tertiary strata. 2. Secondary. 3. Palæozoic. 4. Older Palæozoic. 5. Metamorphic rocks. 6. Plutonic (granitic) rocks.

---

8. GEOLOGY OF ENGLAND.—By an inspection of the Geological Map of England, *Plate I.*, it will be seen that the principal formations successively appear on the surface, somewhat in their true chronological order (*Lign.* 32*), as we pass from the eastern or south-eastern part of the Island to the west or north-west; as, for example, from the coast of Suffolk to Cardigan Bay, or from London to Liverpool. Thus, the Tertiary deposits are spread along the eastern and south-eastern maritime districts; and in proceeding in a north-westerly direction, we successively travel over the Cretaceous, Oolitic, Triassic, Carboniferous, Devonian, Silurian, and Cambrian systems; and, lastly, metamorphic and primary rocks appear.

This distribution of the strata has imparted a peculiar character to the physical geography of England. The Alpine or mountainous districts, which extend north and south along the western portion of England and Wales, from Cornwall to Cumberland, are formed by the elevated masses of the metamorphic, Cambrian, and Silurian rocks. These are succeeded by a band of the carboniferous and triassic strata, with a few intrusions of metamorphic and plutonic rocks, that stretches from the coast of Devonshire, through the midland counties by Leicestershire and Derbyshire, to Newcastle. On the south-east of this tract the oolitic and cretaceous formations, chiefly made up of argillaceous and calcareous deposits, constitute a diversified agricultural district, which extends from the southern shores of Dorset and Hants, to the coast of Yorkshire. The Wealden is exposed in the area between the ranges of the north and south downs of Kent and Sussex. The Tertiary overlie the uppermost secondary strata; they occupy the eastern and south-eastern maritime districts, and form the area on which stands the metropolis of England; they are covered in many places by the drift and alluvial debris, which contain mammalian remains.

After this comprehensive view of the leading characters of the principal rocks and strata of which the present islands and continents are composed, we proceed to a more particular examination of the several formations in their natural sequence, or order of superposition.

9. DRIFT AND ALLUVIUM OF THE MODERN EPOCH.— When explaining, in the previous Lecture, the circumstances under which the remains of terrestrial quadrupeds occur in the superficial deposits, the nature and origin of those beds were briefly described. It is necessary, in this place, to offer a few remarks on the phenomena presented by the drift and other alluvial accumulations of the modern epoch.

The drift and alluvium consist of beds of loam, sand, and gravel, variously distributed; being, in some instances, spread over extensive areas; in others, forming mounds, ridges, and hills of low elevation; in others cresting the summits of abrupt and lofty escarpments: sometimes radiating, as it were, in broad streams from mountain chains; in others constituting a series of terraces and platforms, as if originating in gradual and successive elevations of a sea-coast. The composition of these deposits is as various as their origin. They are generally made up of the detritus of rocks of all ages, promiscuously intermingled, and varying in lithological composition from fine earth and sand, gravel, and pebbles, to large boulders, and rocks many tons in weight. They sometimes consist of the debris of the strata of the adjacent country, but more frequently of rocks that are situated in very remote regions.

It will be apparent to the intelligent reader, that deposits varying so much in mineral characters and structure, must belong to very different epochs, and have been accumulated under very dissimilar conditions. Some are unquestionably ancient shingles or sea-beaches (*see* p. 113): others are sheets of detritus that have been formed along shallow coast-lines, or on the borders of rivers, lakes, deltas, and estuaries: others consist of ridges and mounds of debris heaped up by sudden deluges, or powerful floods that have swept over low tracts of country, or by subaqueous currents, or waves of translation: and others have been produced by the agency of frozen water, either as floating icebergs, or as glaciers. By the nature and state of the shells, bones, and other organic remains, when present, and of the gravel, pebbles, boulders, &c. of which the accumulation of drift or alluvium may consist, the origin of the materials, and the age and character of the deposit, may be more or less satisfactorily determined.*

10. Erratic Boulders.—But there is another class of phenomena which must not be passed over without comment. In many countries rounded and angular boulders of

* Mr. Lyell's "Principles of Geology" should be consulted for a full exposition of this subject.

great size are very abundant, either imbedded in the alluvial sands and gravel, or spread over them. Vast areas, literally covered with boulders, occur in many parts of Europe; enormous masses of stone lying exposed on the surface of the ground, as bare as when left by the retiring waters, and appearing as—

> "Huge rocks and mounds confus'dly hurl'd,
> The fragments of an earlier world."

Many of these boulders are of such magnitude, as more properly to be termed rocks; being from twenty to forty feet high, and weighing many hundred tons.*

Connected with the boulders, and beds of drifted gravel and other coarse detritus, is the occurrence of deep grooves, furrows, striæ, and scratches, on the upper surface of many rocks, and on the sides of such as flank narrow gorges and valleys, or form the slopes of hills and other inclined planes; appearances manifestly resulting from the passage of pebbles, grit, boulders, and angular fragments of hard stone, over exposed surfaces of rocks and strata; in some instances by the action of currents and floods, in others by glaciers and floating ice. In some countries the boulders are not far distant from their parent rocks, and their course and origin may be readily traced; but throughout a great part of Europe, Asia, and America, these waterworn masses must have been derived from very remote regions; and they are distributed in such manner, as to show that their transport could not have taken place under the

* There is a large boulder in the plain near Mount Sinai, which monkish legends identify with the rock of Horeb, whence Moses, by a stroke of his rod, miraculously raised a stream of water for the parching Israelites. It is a block of granite, nearly twenty feet square, which has probably been derived from the neighbouring mountain.—Mr. Greenough's "*Critical Examination of the First Principles of Geology*:" a work abounding in facts and comments of the highest interest.

existing geographical distribution of the land and water, but must have been effected when the present dry land was beneath the sea, and subaqueous currents and icebergs were in active operation. By the former, the accumulations of sand, mud, and gravel may have been deposited; and by the latter, the blocks, however large, may have been detached and transported from their parent rocks to the distant regions they now occupy.* The general course of the drift and erratic boulders in the northern parts of Europe and America, appears to have been from the north and north-west towards the south-east; as if the materials had been brought by polar currents from the northern to the southern regions; hence the term "*northern drift*" is often employed to designate the alluvium and boulders which belong to this category.

Over vast regions of the north of Europe, in Poland, Russia, &c. erratic boulders, chiefly of crystalline and palæozoic rocks, are profusely scattered over the beds of alluvial debris, and upon the exposed surfaces of the older strata. In Sweden, these phenomena are strikingly displayed. The transported blocks occur in clusters, on mounds and ridges of sandy loam termed *osar*, sometimes at a height of from 200 to 300 feet above the adjacent plains. The origin of these widely spread erratic boulders is the granitic and palæozoic rocks of Scandinavia. The recent travels and investigations of Sir R. Murchison have afforded a satisfactory solution of this problem. It appears that at a very remote period, the granitic rocks of Scandinavia were upheaved, and their pinnacles split and shattered to pieces, by the expansive effect of ice; and the fragments and detritus that were carried into the sea by the action of glaciers and

* The power of icebergs in transporting blocks and immense quantities of earthy materials, is graphically elucidated in Mr. Lyell's Principles of Geology, and Sir R. Murchison's Silurian System; see also several memoirs in the American Journal of Science.

torrents, were urged on by subaqueous currents, and large masses transported by ice-floes during the summer season, and deposited on the sea bottom hundreds of miles to the southward. These submarine deposits, covered here and there by erratic boulders dropped by the melted icebergs, were subsequently elevated above the waters, and now constitute the vast plains of Russia and other parts of northern Europe; the transported blocks remaining as durable monuments of the physical changes which converted the ocean-bed into dry land.*

In England there are no tracts covered by boulders of such magnitude as to be comparable with the instances above adduced; but the same phenomena are observable on a smaller scale, in various districts. Boulders of the granites, porphyries, syenites, and slaty rocks of the Cumberland mountains, are dispersed northward towards Carlisle, southward towards the bay of Morecombe, and eastward to the foot of the Pennine chain. They may be traced from Lancaster "at intervals through the comparatively low country of Preston and Manchester, lying between the sea and the Yorkshire and Derbyshire hills, to the valley of the Trent, the plains of Cheshire and Staffordshire, and the vale of the Severn, where they occur of considerable magnitude."† The quartz rocks of the Lickey Hills, between Birmingham and Bromsgrove, in Worcestershire, have yielded immense beds of pebbles, which are thickly spread to the south and east, and even into the valleys of the Evenlode, Cherwell, and Thames, and into the gorge of the chalk downs as far as Reading.‡

* See "Geology of Russia," for a full consideration of the "*Scandinavian Drift*," and the phenomena connected therewith.

† Professor John Phillips's "Treatise of Geology."

‡ See "A Description of the Quartz Rock of the Lickey Hill in Worcestershire, and of the strata immediately surrounding it;" by the Rev. Dr. Buckland.—*Geol. Trans.* vol. v. p. 506. This is a masterly

In some of the examples quoted, the surface of the country is not unfavourable to the passage of such materials as compose the drift, if urged on by floods or sudden rushes of water; and if it be assumed that the Cumberland mountains were of sufficient altitude, during the boulder period, to accumulate glaciers, the torrents produced by the melting of the ice in the summer seasons, would account for some of these beds of transport. But in many instances the physical configuration of the surface forbids this interpretation; and the subaqueous condition of the country, and the action of currents, waves of translation, and ice-floes, offer the most satisfactory explanation of the phenomena.*

11. The Tertiary Formations.—We now enter upon the consideration of the *Tertiary Formations*,—those ancient deposits of seas, rivers, and lakes, which belong to the period immediately antecedent to that which is marked by the prevalence of existing species of quadrupeds, and of extinct elephantine forms, as the Mammoth, Mastodon, &c. and subsequent to the deposition of the uppermost secondary formation, the *Chalk*.

The discoveries of MM. Cuvier and Brongniart, about thirty years since, in the immediate vicinity of Paris, first

review of some of the principal examples of drift in that part of England. The young geologist in perusing this memoir must, however, bear in mind, that the facts so graphically described, do not afford any evidence of a recent universal deluge; a hypothesis maintained by the most eminent geologists of that period (1821).

* Our limits will not admit of any further notice of the erratic blocks of England; but it may interest the reader to know that there is a very instructive example of a ridge of drift, probably deposited by an ice-floe, in the immediate vicinity of London, namely, Muswell Hill, beyond Highgate; which is capped with an alluvial bed of pebbles, boulders, and fossils of rocks of all ages, from the chalk to below the carboniferous limestone inclusive. The collections of Mr. Wetherell and Mr. Toulmin Smith, of Highgate, contain characteristic fossils of the oolite, lias, mountain limestone, &c., with blocks and pebbles of granite, gneiss, and other primary rocks, all obtained from Muswell Hill.

directed attention to the important series of strata now distinguished by the name of *Tertiary* (*see* p. 201). The fossil extinct pachyderms, whose bones abound in the gypsum quarries of Montmartre, were by the genius of Cuvier recalled, as it were, into existence, and the philosophers of Europe saw with astonishment, whole tribes of unknown and extraordinary types of being, disinterred from rocks and mountains, which had previously been considered as destitute of scientific interest. Analogous strata, some of a marine, and others of a lacustrine and fluviatile character, were soon found to be spread over many parts of the continents of Europe and America; forming a series so extensive, and requiring such a lapse of time for its production, that the Chalk, hitherto regarded as comparatively of modern origin, is carried back to a period incalculably remote. The tertiary system may be said to constitute a series of strata which unites the present organic kingdoms with the past; for while the most ancient contain species related to forms that occur in the secondary formations, the most recent insensibly glide into the modern deposits, and abound in fossil remains of recent species of animals and plants, associated with many that are not now known to exist.

Mr. Lyell has adopted a classification of the tertiary strata, founded on the relative proportion of recent and extinct species of animals, which any given series of beds may contain; and as shells occur in most of the strata in great abundance, and in good preservation, he has selected these types of animal organization, as the distinctive characters of the principal subdivisions. Though in the present state of our knowledge this method is of great utility, it will probably require considerable modification; and, perhaps, must hereafter be altogether abandoned; for it cannot be doubted, that strata in which no recent species have yet been found, may yield them to more diligent and extended researches; and the relative proportions of recent and extinct organisms, may be found to occur in a very different ratio, from that which is assumed as the basis of this arrangement.*

12. Classification of the tertiary.—According to this system the tertiary strata form three principal groups, each characterized by the relative proportion of the recent and extinct species of shells; and a nomenclature has been

* This anticipation is already in some measure confirmed; for existing species have been found in the most ancient tertiary deposits: and several secondary shells, fishes, &c. in tertiary strata, and even living in the present seas. An eminent Italian naturalist (Dr. A. Philippi), in an elaborate review of the mollusca of the South of Italy in reference to the shells of the tertiary period, has come to the following conclusion:—"That the tertiary formations of Southern "Italy will not admit of any chronological subdivisions, for we cannot "trace the limits which separate the tertiary from the diluvial, nor "the diluvial from the existing period; neither can we make use of "the terms *eocene, miocene,* and *pliocene,* with reference to the South "Italian deposits, so far as these expressions refer to a per centage of "extinct to existing species; and we would suggest that such terms "are also uncertain and arbitrary with regard to other districts."—*Philippi:* Proceed. Geol. Soc. Feb. 1846.

Immediately after the last tertiary deposits, the modern period begins, when all the now European species first appear: the cavern animals and some of the large pachyderms, are referable to the earliest age of this era. Inundations, more or less local, occasioned by the elevation of some tracts of dry land, and the subsidence and submergence of others, filled up the caverns and destroyed the races of carnivora.

In the diluvial gravel in the Canton of Geneva, there have been found bones of many species of animals which still inhabit the surrounding country; as for example, the mole, fox, sheep, ox, pig, rat, mouse, green frog, lizard, &c. These remains occur beneath distinctly stratified beds of gravel, at a depth of ten feet below the cultivated soil. These animals must therefore have been indigenous to this part of Europe, when the deposition of the diluvium was going on, and prove the continuance of species uninfluenced by those geological changes which occasioned the last elevation of the land.—*M. Pictet on the Diluvial Deposits of the Canton of Geneva.*

adopted expressive of the characters upon which the classification is founded. These divisions are as follow:—

1. The Pliocene (*signifying more new or recent*).—Tertiary strata, in which the shells are for the most part recent; containing about ten per cent. of extinct species; these beds are subdivided into the newer and older *pliocene*.
2. The Miocene (*denoting less recent*):—containing a small proportion, about twenty per cent., of recent species of shells.
3. Eocene (*signifying the dawn of recent, in allusion to the first appearance of recent species*):—containing very few recent species; not more than three or four per cent.

The marine are in many instances associated with freshwater deposits, and the general characters of the system are alternations of marine with lacustrine strata. The districts occupied by these beds in Europe, are exceedingly variable in extent, as Mr. Lyell has shown in a very ingenious map of the tertiary seas;* and it appears certain, that during the tertiary epoch, there were large areas alternately the sites of freshwater lakes and inland seas, and that these transitions were dependent on oscillations in the relative level of the land and water.

13. Fossil shells.—The geological evidence afforded by fossil remains has already been exemplified; but our remarks have hitherto in a great measure been restricted to the relics of terrestrial quadrupeds. The shells of mollusca, however, from their durability, often escape obliteration under circumstances in which all traces of the higher orders of animals are lost, and they become, therefore, of the utmost importance in the speculations of the geologist. In loose sandy strata, they often occur in a high degree of perfection; in mud and clay, in a fragile state; in some instances they are silicified; and many limestones are wholly composed of shells, cemented together by calca-

* Principles of Geology, vol. i. p. 214.

reous spar. Molluscous animals* are divided into *mollusca*, properly so called, which are covered with a single shell, as snails, periwinkles, &c. ; and *conchifera*,† having a shell with two valves, as oysters, scallops, &c. The former are of a higher organization than the latter, having eyes, and a distinct nervous system ; the latter have neither eyes nor head, and are therefore called *acephala*.‡ Some genera are herbivorous, living exclusively on vegetables ; others are carnivorous ; and many have a retractile proboscis, furnished with a rasp, by which they can perforate wood, shells, stone, and other substances. The shells of the carnivorous testacea are also generally provided with a channelled or grooved beak, for the reception of the fleshy syphon by which the sea water is conveyed to the respiratory organs (*Lign.* 38, *fig.* 3, 4, 5) ; while the herbivorous have the opening of the shell entire (*Lign.* 39, *fig.* 3, 5, 6, 7). Some tribes are exclusively marine, others can only live in fresh-water, while many are restricted to the brackish waters of estuaries. Their geographical distribution is alike various : certain highly organized forms (the *Cephalopoda*) inhabit deep waters only, and are provided with an apparatus by which they can rise to the surface ; while others are littoral, that is, live in the shallows along the sea coasts ; many exist in quiet, others in turbulent waters ; some are gregarious, like the oyster, while others occur singly or in small groups. All these varieties of condition are more or less strongly impressed on their shelly coverings, which may be regarded as their external skeletons ; and the experienced conchologist is generally enabled, by the peculiar characters of the shell, at once to determine the economy and habits of the animal, and consequently the physical conditions in

* Soft-bodied animals. † Shell-bearing animals.

‡ Having no head.

§ Medals of Creation, vol. i. chap. 12, p. 363.

which it was placed.* In this point of view, fossil shells become objects of the highest importance to the geologist, since they are frequently the only indications of the circum-

* There is, however, a source of error that cannot always be guarded against: great changes are produced in shells by merely local influences, and these are often mistaken for specific distinctions. Professor E. Forbes, whose investigations have so beautifully elucidated many of the phenomena relating to the submarine distribution of the mollusca, and other aquatic animals, affirms that many parts of the sea are too deep to admit of the existence of any animals or vegetables; and therefore, that deposits of vast thickness, in which no organic remains can occur, may be forming in those profound abysses at the present time.

He remarks, that the absence of fossils in any marine stratum, is no proof that when the bed was deposited, there might not have existed above it a sea teeming with life. Now, admitting to the full extent the facts and inferences adduced by this accomplished naturalist, in proof of the intimate relation existing between the depth of water and the mineral character of the sea-bottom, and the prevailing species and genera of mollusca; and entirely concurring in the opinion that the absence of fossils in any strata, ought not to be admitted as proof that the waters which deposited them were destitute of living things, yet I cannot admit as a corollary from these premises, that very deep sea deposits must necessarily be destitute of organic remains. The materials, whether organic or inorganic, that are carried into the ocean by streams and rivers, and the detritus of the cliffs and coasts transported by the powerful currents which traverse the entire area of the ocean, and the sediments which accumulate in the most profound abysses, may imbed organic remains, equally with those which are deposited in shallower waters (*see* p. 70). With the exception of those strata in which the local conditions prove that the shells, corals, &c. lived and died on the areas where their remains are imbedded, the prevalence or absence of fossil remains appears to have principally depended on the influence of submarine currents, tidal waves, &c. Nothing is more common than to find over vast regions a like intermixture of shallow and deep-water species and genera,—as rostellariæ, turritellæ, melaniæ, mussels, &c. collocated with ammonites and nautili, fishes, radiaria, &c. that when living inhabited geographical zones of very different depth: and this, too, not only in littoral beds, but likewise in strata, which, from the absence of gravel, sand, and other alluvial detritus (as in the white chalk), we must infer to have been deep sea deposits. We have, then, stances under which deposits were accumulated.* I return from this digression to the consideration of the phenomena presented by the several groups of the tertiary formations.

14. LITHOLOGICAL CHARACTERS OF THE TERTIARY STRATA.—The predominating characters of the tertiary system are alternations of marine beds with those of lacustrine and freshwater origin. A large portion of the beds is arenaceous, with intervening strata of clay and marl. Shingles, the remains of ancient sea-beaches, abound in some localities, and often occur as a conglomerate or puddingstone, as in Hertfordshire (p. 101); or as a ferruginous breccia, as at Castle Hill, near Newhaven, on the Sussex coast.† The ruins of the Chalk are everywhere recognizable in the immense beds of water-worn flints, which contain shells and zoophytes peculiar to the cretaceous system. Large erratic boulders and blocks of crystalline sandstone are of frequent occurrence on the chalk downs, and have probably been derived from the upper beds of the Bagshot sand. In the vicinity of Brighton, blocks of ferruginous breccia are scattered over the surface of the Downs, and masses of quartzose sandstone, of a saccharine structure, occur at Falmer, and in Stanmer Park: some years since there was a large rock of this stone in Goldstone Bottom, near Brighton.

In most of the gravel beds around London there are numerous blocks of siliceous breccia and conglomerate. In some of the tertiary series limestone predominates, and alternates with sands and marls of great variety and brilliancy of colour; beds of gypsum, and siliceous nodules resembling the flints of the chalk, also occur. Such are

no conclusive evidence that the so-called *azoic* strata were formed before the existence of animated beings, or that any beds of later data, destitute of fossils, were deposited in deeper water than many of the fossiliferous deposits.

* See Medals of Creation, vol. i. p. 363.

† Geology of the S. E. of England, p. 55.

the leading lithological features of this system of deposits, which we will now examine more in detail.

The distribution of the tertiary strata over Europe, appears to be in areas more or less well defined. In our own Island, there are the basins of London and Hampshire, which probably were originally united ; and the remains of other series of beds in Yorkshire, Norfolk, Suffolk, Essex, &c. The metropolis of France is situated within the confines of a tertiary area; and in the southern and northern provinces of that country, there are extensive tracts of similar deposits. In Auvergne, they are associated with lavas and scoriæ of ancient volcanic eruptions, and constitute a district of unrivalled geological interest. In the Sub-Apennines, they are largely developed ; and in other parts of Sicily and Italy they insensibly pass into vast beds of modern origin, which are still in progress of formation.

In the United States, tertiary marls, clays, and sands, are spread over considerable areas, between the Alleghany mountains and the Atlantic, resting upon sands and marls belonging to the chalk formation. In Maryland and Virginia, there are extensive deposits of this class, remarkable for their organic composition, as we shall hereafter have occasion to notice.

15. Subdivisions of the Tertiary System. — The divisions of the Tertiary system, adopted by geologists, are concisely expressed in the following synopsis.*

I. Pliocene ; or *Upper Tertiary.*	Freshwater and marine strata, containing but a very few extinct species of shells. Abundance of existing species, indicating a marine fauna not essentially different from that which now prevails in the present seas.	Fluvio-marine beds on the eastern coast of England. The Norwich Crag. Sub-Apennine deposits ; and those of Palermo, and other parts of Sicily.

* See Mr. Lyell's Elements of Geology, vol. i. p. 284.

II. Miocene; or *Medial Tertiary.*	Strata containing from twenty to thirty per cent. of extinct species of shells. The temperature of the sea, as indicated by the shells, of a sub-tropical character.	The *Crag* of the maritime parts of Essex, Suffolk, and Norfolk. Faluns of the Loire. Beds in the Val d'Arno.
III. Eocene; or *Lower Tertiary.*	Marine and freshwater deposits; the recent species of shells amounting to scarcely more than five per cent. The prevailing forms indicate a marine temperature almost equal to that of the existing tropical seas.	The series of deposits, comprised in the tertiary basins of London, Hampshire, Paris, and the Netherlands.

16. Upper tertiary, or pliocene.—From the large proportion of recent species of shells which occur in the pliocene strata, the beds have all the characters of a modern aggregate, as in the extensive and beautiful collection from Palermo before us, for which I am indebted to the liberality of the Marquess of Northampton.

They are from a range of hills, which rises to an elevation of about 200 feet above the level of the Mediterranean, immediately behind Palermo. These hills are in a great measure composed of coarse limestone, made up of friable shells, which are frequently in an admirable state of preservation; in some examples preserving even their markings and natural polish. The elegant and picturesque manner in which they are occasionally grouped renders them objects of great beauty and interest. These fossils, with but few exceptions, are of species still living in the adjacent sea; a proof that when the limestone was formed, the same condition of the basin of the Mediterranean existed as at present, and that it was uninfluenced by the elevation of that portion of its ancient bed, which now forms the range of hills.

In other parts of Sicily, limestone, blue marl, beds of shelly calcareous breccia, and gypseous clay occur, intermingled with volcanic products. In the *Val di Noto* there is a remarkable assemblage of these deposits, which is thus described by Mr. Lyell :—*

"The rising grounds of the Val di Noto are separated from the cone of Etna, and the marine strata on which it rests, by the plain of Catania, which is elevated above the level of the sea, and watered by the Simeto. The traveller passing from Catania to Syracuse, by way of Sortina and the valley of Pentalica, may observe many deep sections of these modern formations, rising into hills from one to two thousand feet in height, and entirely composed of sedimentary strata, with recent shells; these are associated with volcanic rocks. The whole series of strata, exclusively of the volcanic products, is divisible into three principal groups. 1. The *uppermost*, compact limestone in laminated strata, with recent shells; total thickness, from 700 to 800 feet. 2. Calcareous sandstone, with schistose limestone. 3. Laminated marls and blue clays."

The above groups contain shells and zoophytes of the same species as those from Palermo just noticed. The large scallop (*Pecten jacobæus*), which at the present day is profusely strewn on the Sicilian shores, is abundant, and beautifully preserved in the compact limestone; associated with immense numbers of very minute foraminifera, of species that now swarm in the waters of the Mediterranean. Leaves of plants and stems of reeds are of frequent occurrence.

The Apennines, which extend through the Italian peninsula, are flanked, both on the side of the Adriatic and the Mediterranean, by the Sub-Apennines, a low range composed of tertiary marls, sands, and conglomerates, some

* Principles of Geology, vol. iii. p. 388.

of which were cotemporaneous with the Crag, while others belong to a more ancient epoch. These beds have resulted from the waste of the secondary rocks, of the Apennines, which were dry land before these strata were deposited.

17. MIOCENE, OR MIDDLE TERTIARY.—*The Crag.* The miocene are defined as strata containing but a small proportion of recent species of shells, seldom exceeding 20 or 30 per cent.; but there are exceptions to the rigid application of this rule in many of the strata comprised in the middle tertiary. Near Bordeaux, and in Piedmont, Hungary, and other parts of the continent, groups of miocene strata occur, and have been described by Mr. Lyell, and other geologists.*

In England a very interesting assemblage of pliocene and miocene strata is spread over considerable areas, along the maritime parts of the eastern counties, Essex, Suffolk, and Norfolk,—and is called the *Crag;* a provincial term, signifying gravel. These beds extend along the coast forty or fifty miles, and form a tract which in some parts is ten or twelve miles in breadth (*see Plate* I.). The foundation rock of that part of England is the white chalk, which is more or less covered by the London eocene clay, on which the lower Crag is superimposed. The Crag strata consist of loam, clay, sand, and gravel, containing beds of marine shells and corals; many of the layers being wholly made up of shelly and coralline detritus. In the upper part of the series there are intercalations of fluviatile deposits; and over all a bed of silt, containing mammalian remains, which insensibly blends with the superficial alluvium of the country.

Mr. Edward Charlesworth, to whom belongs the merit of having first accurately investigated and interpreted the zoological characters of the Crag, and pointed out the

* See Elements of Geology, vol. i. chap. xiv.

natural groups of this series, has established the following subdivisions of the deposits that occupy the eastern coast of England :—

1. *Coralline* or *lowermost Crag.* A series of calcareous and marly strata, loose white sands, layers of shells and corals, and concretionary bands of stone. It abounds in shells, echini, sponges, and corals, (especially of the genus *Fascicularia*,) and these occur in so perfect a state as to indicate that they lived and died on the spot; for many of the sponges and corals are in the upright position in which they grew. This group is upwards of twenty feet in thickness, and extends along the coast of Suffolk, over an area of twenty miles in length and three or four in breadth.
2. *Red* or *Norfolk Crag.* So named from its deep ferruginous colour. It consists principally of quartzose sand, with comminuted and waterworn shells, corals, bones and teeth of fishes, and other fossil remains. These beds, when occurring in the same locality, are invariably superimposed on the Coralline Crag. They attain a thickness of upwards of forty feet, and abound in marine shells, especially numerous species of *Murex*, *Buccinum*, and *Fusus*; among the latter is the *Fusus contrarius*, (so named because the spiral convolutions pass from the right to the left, instead of in the opposite and ordinary direction,) a well-known shell, formerly in great request among collectors.*
3. *Mammaliferous*, or *fluvio-marine Crag.* Sandy loam, and clay, more or less charged with shelly detritus; it occurs in certain localities at Southwold, Norwich, Cromer, &c. and contains bones and teeth of several extinct mammalia, associated with those of existing and indigenous species.
4. Insulated patches of lacustrine beds with mammalian remains. Above the whole of these deposits, is the usual alluvial sediment and drift, in which are vast numbers of bones and teeth of Elephants and other pachyderms, including a species of Mastodon, and the Irish Elk.†

---

* See Parkinson's Organic Remains of a former World; vol. iii. pl. 6, fig. 5.

† Of the Mastodon thirteen teeth have been found. More than thirty years since, tusks of mammoths, horns of Bos and Aurochs, and antlers of the Irish Elk, from near Walton Nase, in Essex, were sent to me by G. B. Greenough, Esq.

To complete this slight sketch of the geology of the district, we may observe that there are some insulated patches of lacustrine silt and clay, containing extinct mammalian remains, associated with those of living indigenous species; these strata appear to be post tertiary.

The Coralline-crag has yielded to the researches of Mr. Searles Wood and others, upwards of 400 species of shells; numerous corals; teeth of several fishes of the Shark family, some of large size (*Carcharias megalodon*); teeth of Eagle-rays (*Miliobatis*); and ear-bones (*otolithes**) of the Sperm-whale, and other cetaceans. The corals are of unknown genera, and the echinoderms, of which there are sixteen species, are distinct from any in the adjacent seas.

From the Red Crag, nearly 300 species of shells have been obtained, of which about one-half also occur in the lower Crag. The number of extinct (or more properly, *unknown*) species, is about 30 per cent, in the former, and 20 per cent. in the latter group. Microscopic shells of foraminifera are abundant. Terebratulæ of great size are often met with; specimens six inches long have been obtained by Mr. Charlesworth.

The Mammaliferous Crag has evidently originated in deposits of silt and sand, brought down from adjacent land by a river, or streams of fresh water, into a creek or bay in which marine detritus was accumulating. With numerous marine shells, it contains some fluviatile and terrestrial species; and in it have been found teeth of the Mastodon, Ursus spelæus,† and other contemporaneous fossil mammalia.

The uppermost beds appear to be entirely lacustrine or fluviatile, for they contain fresh-water shells and bones and teeth of land quadrupeds; comprising those of field-

* Medals of Creation, vol. ii. p. 603.

† Mag. Nat. Hist. vol. iii. p. 450.

mice, rat, and beaver; and the large extinct form of the latter, that occurs in the mammoth drift of Russia (the *Trogontherium*, see *ante*, p. 154); a portion of the jaw of an opossum, and bones of unknown species of water-mole, deer, roebuck, monkey, and bat.*

The passage of the mammaliferous crag into the alluvium, is in many places so imperceptible, that no line of chronological separation can be drawn; and our previous remarks on the deposits of the valley of the Thames, render farther comment unnecessary.

18. EOCENE, OR LOWER TERTIARY DEPOSITS.—I now proceed to the consideration of the *Eocene*, or those tertiary strata which are of the highest antiquity, and occupy basins or depressions of the chalk, where that formation constitutes the fundamental rock of the country. Every step of our progress will now be replete with increased interest, and the relics of new and extraordinary forms of being will appear before us. I shall pass rapidly over the stratigraphical character of these rocks, that our attention may be more fully directed to the organic remains which they inclose.

I will first describe the geographical distribution and general characters of a few of the principal groups, and the more remarkable fossil animals and plants; and then survey those regions of central France, of the Rhine, and of South America, which have been the scenes of active volcanoes during the tertiary epoch.

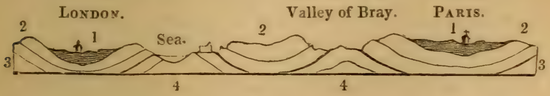
It may be regarded as a singular coincidence, that the capitals of Great Britain and France are located on strata of the same geological age. Paris is situated on a vast alternation of marine and fresh-water beds, lying in a depression of the chalk; the latter forming the boundary of the area in which the city is placed. London also is built

* At Ostend, near Bacton, Norfolk; see Medals of Creation, vol. ii. pp. 859—867. Professor Owen has figured and described the most important of these relics in "British Fossil Mammalia."

on clays, sands, and shingles, filling up a basin of cretaceous strata, the margin of which skirts the area of the tertiary on the south, but leaves it open to the sea on the east. In Hampshire, and on the northern part of the Isle of Wight, a series of contemporaneous lacustrine beds, with inter-

LIGN. 33.—TERTIARY BASINS OF PARIS, LONDON, AND HANTS.
(From Mr. Webster's Map; Geol. Trans. Vol. II.)

spersions of marine deposits, in like manner rests upon the Chalk. The relative situation and comparative extent of these three basins are shown in the map (*Lign.* 33); and



LIGN. 34.—SECTION FROM HERTS, TO SENS, IN FRANCE.
(From Mr. Lyell's Elements of Geology.)
1, 1, Tertiary; 2, 2, Chalk; 3, 3, Greensand; 4, 4, Wealden.
The shaded sites of London and Paris, and of part of Hants and the Isle of Wight, indicate the tertiary deposits.

the ideal section (*Lign.* 34), from Hertfordshire across the British Channel, to Sens in France, explains the position of the London and Paris basins, and the underlying chalk and wealden deposits.

19. THE PARIS BASIN.—The Paris basin is from east to west about 100 miles in extent, and 180 from north-east to south-west ; the greatest total thickness of the beds, or in other terms, the depth passed through to reach the chalk, amounts to several hundred feet.

The strata, commencing with the lowermost, or most ancient, present the following characters :—

1. *The lowermost.* Chalk flints, broken, and partially rolled, sometimes conglomerated into ferruginous breccia.*
2. *Plastic clay, and sand.* Strata of clay and sand, with fresh-water shells, drifted wood, lignite, leaves, and fruits; with bands of limestone containing marine shells.
3. *Siliceous limestone,* or *Calcaire grossier;* with fresh-water and terrestrial shells and plants, and a coarse, marine, compact limestone, passing into calcareous sand, and abounding in marine shells.—These beds often alternate, and are considered by M. Constant Prevost to be contemporaneous formations; the marine strata having been formed in those parts of the basin which were open to the sea, and the fresh-water limestone, by mineral waters poured into the bay from the south; the Continent being situated then, as now, to the south, and the ocean to the north. Layers of *miliolite* limestone,† almost entirely composed of microscopic shells of foraminifera, occur in this part of the basin.
4. *Gypseous marls, and limestones;* with bones of terrestrial animals, and fluviatile shells. These are supposed to have been discharged by a river which flowed into the gulf; the gypsum being precipitated from water holding sulphate of lime in solution, in the same manner as the travertine or calcareous tufa, of which we have already spoken (p. 74).
5. *Upper marine formation,* consisting of marls, micaceous and quartzose sand, with beds of sandstone abounding in marine shells.

---

* A layer of this kind is very common on our South Downs, immediately under the turf.

† So called from its inclosing immense quantities of a minute shell, named *Miliola.*

6. *Upper fresh-water marls,* with interstratified layers of flint, containing seed-vessels of aquatic plants (*Charæ,* p. 86), and animal and vegetable remains. These beds are attributed to lakes and marshes, which existed after the marine sands had filled up the basin.

From this rapid sketch, we perceive that the strata which occupy the Paris basin have been produced by a succession of changes, that readily admits of explanation by the principles enunciated in the previous lectures. Here we have an ancient gulf of the chalk, which was open to the sea on one side, while on the other it was supplied by rivers charged with the spoils of the country through which they flowed, and that carried into the sea the remains of animals and plants, with fresh-water shells; and there were occasional introductions of mineral waters. Changes in the relative level of the land and sea took place, and thus admitted of new accumulations upon the previous deposits; lastly, the country was elevated to its present altitude above the sea. Mutations of this kind, as we have already seen, are in progress at the present moment, and afford a satisfactory elucidation of these interesting phenomena. I reserve for the present any remarks on the fossils of the Paris basin, and pass to the examination of synchronous strata in our own Island.

20. The London Basin.—The tertiary deposits on which the metropolis of England is situated are spread over a considerable area, which is bounded on the south by the North Downs, and extends on the west beyond High-elm Hill, in Berkshire. It is flanked on the north-west by the Chalk hills of Wiltshire, Berkshire, Oxfordshire, Buckinghamshire, and Hertfordshire. On the east it is open to the sea; the Isle of Sheppey, situated in the mouth of the Thames, being an outlier of the same deposits.* These beds extend

* See Mr. Webster's paper in the Geolog. Trans. vol. ii.; and Conybeare and Phillips's Geology of England and Wales.

over Essex, a considerable part of Suffolk, Epping and Hainault forests, the whole of Middlesex, and a portion of Bucks. The tertiary deposits comprised in this series are subdivided as follows :—

Bagshot Sands, and Brackleshan Clays;—sands, sandstones and foliated marls, and concretionary masses of siliceous sandstones; with a medial group of argillaceous beds.

London Clay;—a tenacious blueish-black clay, with layers of septaria, intercalated sands, shingles and conglomerates.

With the first division, Mr. Prestwich places the *Bracklesham clay*; and with the latter the *Bognor* rocks: beneath the whole are the mottled clays of Alum Bay, and the *Newhaven* and *Woolwich* beds, all of which are included in the term *Plastic clay*.

The site of the metropolis and its environs consists of the London clay, which abounds in marine remains, and constitutes the great mass of the materials that fill up this ancient gulf of the ocean. Immediately upon the chalk, however, there are thick beds of sand and mottled clay, called Plastic clay (from the *Argile plastique* of the Paris basin), in which fresh-water shells, plants, and drifted wood are found in some localities. In other instances, layers of green sand lie upon the chalk, which at Reading contain immense quantities of oyster shells : a similar accumulation of shells occurs near Norwood, and at Headley in Surrey, a few miles from Reigate. At Bromley, in Kent, there is an extensive bed of oyster-shells with pebbles of chalk-flints interspersed, the whole being cemented together by a calcareous deposit into a remarkable shell conglomerate, which is in much request for grottoes and ornamental rockwork.

The London clay is found immediately beneath the gravel which so generally constitutes the subsoil of the metropolis ; it is of great extent, and varies from 300 to 600 feet in thickness. The blue clay produces a dark, tough soil, with occasional intermixtures of green and ferruginous sands, and variegated clays. It abounds in layers of spheroidal nodules of indurated argillaceous limestone, internally traversed by veins of calcareous spar, that radiate from the centre to the circumference. From the appearance of septa or partitions which this character confers, these concretions are called *Septaria:* shells and other organic remains frequently form the nuclei of these nodules, which are used in prodigious quantities for cement. Many other argillaceous strata contain concretionary spheroids of this kind: beautiful specimens are obtained from the Lias, and Oxford clay, and are cut and polished for tables and other articles. The septaria are commonly disposed in horizontal lines, and lie at unequal distances from each other. Brilliant sulphuret of iron abounds in the clay, and permeates the septaria and many of the organic remains. Crystallized sulphate of lime, or selenite, is also common in these and other argillaceous strata. The cuttings through Highgate Hill, to form the archway; the excavations in the Regent's Park; and, more recently, the tunnels carried through a part of the same ridge of clay at Primrose Hill, in the line of the Birmingham railroad; and the cuttings of other railways, and the explorations, by wells, over the whole area around London, have brought to light such prodigious quantities of organic remains, that the fossils of this deposit are almost universally known. The late Mr. Sowerby called early attention to these productions, the first plate in his *Mineral Conchology* being devoted to the nautili and other shells of the London basin. Immense numbers of marine shells of extinct species; crabs, lobsters, and other crustaceans; teeth of sharks, and of many other genera of fishes; bones of crocodiles, turtles, serpents and birds; leaves, fruits, stems of plants, and rolled trunks of trees perforated by boring shells;—occur throughout these strata, but are located in greater abundance in some spots than in others. The clay and gravel pits at Woolwich, on the banks of the Thames, are full of fresh-water univalve shells; and at Plumstead, Bexley, and other places, marine bivalves occur in clay, and in indurated argillaceous limestone.*

21. THE ISLE OF SHEPPEY.—The Isle of Sheppey is entirely composed of the London clay, and the thickness of the beds is upwards of 550 feet. It has long been celebrated for its organic remains; and I may observe, that the discovery of seed-vessels and stems of plants in pyritous clay, in a visit which I made to Queenborough, when a youth, tended to confirm my early taste for geological researches. The cliffs on the north of the island are about 200 feet high, and consist of clay abounding in *septaria*, which are washed out of the cliffs by the action of the sea, and collected for cement. The organic remains are, however, unfortunately so strongly impregnated with pyrites, that the collector often finds the choicest fossil fruits in his cabinet, like the fabled apples of the Dead Sea, one moment perfect and brilliant, and the next decomposed and fallen to pieces, leaving only an efflorescent sulphate of iron. A solution of isinglass in spirits of wine, applied as a varnish, is one of the best preservatives. The same species of animal and vegetable remains that are found in the blue clay of the metropolis, are also met with in profusion in the Isle of Sheppey.†

Fruits, seed-vessels, with stems and branches of trees, of a tropical character, probably drifted by currents into the gulf of the London basin, occur in such abundance and variety in the Isle of Sheppey, that the existence of a group of spice islands at no great distance, seems necessary to account for so vast an accumulation of vegetable productions. The seed-vessels are referable to several hundred species; some are related to the Cardamom, Date, Areca, Cocoa,

* Messrs. Wetherell and Edwards have fine collections of the Highgate fossils.

† See Medals of Creation, vol. i. p. 175.

Cotton-plant, Bean, Cucumber, Acacia, Pepper, &c.* The wood found in the Sheppey clay, is generally in the state of a pyritous lignite, with the ligneous fibres and circles of growth well defined ; it is often veined with brilliant pyrites, and the fissures and cavities are frequently filled with that mineral. It is rarely that any considerable mass of this wood is found free from the ravages of a species of teredo, resembling the recent *Teredo navalis*, or *borer*, which inhabits the seas of the West India islands. The shelly tubes sometimes remain, but their cavities, as well as the perforations in the wood, are more or less filled up with pyrites, indurated clay, argillaceous limestone, or calcareous spar ; and specimens, when cut and polished, exhibit interesting sections of these meandering channels. In these specimens, which I collected in 1811, from the cuttings of the canal in the Regent's Park, the structure of the wood, and the form of the shells, are beautifully displayed.†

22. Bagshot sands and clays.—At Highgate and Hampstead, Purbright and Frimley Heaths, in Surrey, and on Bagshot Heath, extensive beds of siliceous sands, with a middle group of clays and marls occur, but they contain very few traces of organic remains ; the fossils hitherto observed are principally casts of shells of Bracklesham species. In cutting through the summit of Goldsworth Hill, four miles north of Guildford, on the line of the London and Southampton railway, teeth and other remains of several genera of fishes were discovered ; the teeth of sharks, and the palates of rays, were the most numerous. Teeth of the saw-fish (*Pristis*), and of several new genera of cartilaginous fishes, were also collected.‡

* See Figures and Descriptions of the Fossil Fruits of the London Clay ; by I. S. Bowerbank, Esq. F.R.S.

† For a particular account of the Island and its fossils, see "*Excursion to the Isle of Sheppey* ;" in Medals of Creation, vol. ii. p. 897.

‡ See Geology of the Isle of Wight, p. 84.

The boulders and masses of sandstone, which are abundant in some of the chalk valleys, and on the flanks of the Downs, and are called *Sarsden-stone*, or *Druid sandstone*, from being the principal material employed in the construction of Stonehenge, and other Druidical monuments, have been derived from the lower Bagshot sands. In many of the wastes and unproductive heaths around London, the arenaceous deposits of this group form the subsoil; and they constitute that picturesque spot, Hampstead Heath, and cap Highgate Hill and the adjacent heights. The beds of shingle associated with the sands, have unquestionably been derived from the ruins of the chalk formation.*

23. NATURE OF SPRINGS.—From the alternation of sands and other porous strata with stiff impervious clays, throughout the London basin, the metropolitan district is favourable for obtaining water by means of the borings termed Artesian wells, by which means perennial fountains are made to rise from the natural reservoir in the lowermost beds of sand. The nature of these wells is easily explained. The descent of moisture from the atmosphere upon the earth, and its escape into the basin of the ocean by the agency of streams and rivers, were noticed in the first lecture. The rain falling on a gravelly or porous soil, descends through it, till its progress is arrested by a clayey or impervious stratum, which thus forms a natural tank that receives the water, and a subterranean reservoir or pool will be the result,

* Mr. Prestwich, whose indefatigable and able researches have largely contributed to establish correct views of the natural groups of which the British tertiary consist, regards the Bagshot sands as a triple series; arenaceous strata constituting the upper and lower, and argillaceous beds the middle division: to this last he refers the blue clay of Bracklesham, Southampton, Barton, &c. However this may be, the geological character of the eocene system of the London and Hampshire basins, is that of an extensive marine formation, with a few intercalations of fluviatile deposits in the lower groups, and passing into a freshwater and lacustrine condition in the upper.

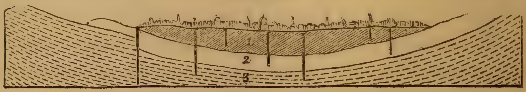
according to the direction and configuration of the overlying bed of clay. This state of things will continue, till, by an increased supply, the water rises above the level of the basin or channel, and either overflows, or escapes through fissures in the rocks, to another level. If the course of the waters be subterranean, the beds of slightly coherent stone are worn away, and chasms or caverns are formed; hence the underground rivers and streams, of great extent, which occur in many places (p. 56); but if the water find its way to the surface, a spring bursts forth. This is the nature of all springs, except those which arise from very great depths, such for example as the thermal waters of many countries; these probably originate from the condensation of steam, evolved through fissures by volcanic agency. Streams impregnated with the mineral substances contained in the strata through which they flow, are called mineral waters. Those in the tertiary strata near Epsom, contain sulphate of magnesia, whence the name of Epsom salt, given to this substance wherever it occurs.*

24. ARTESIAN WELLS.—But pervious strata frequently alternate with others which are not so; and they, likewise, form basins, the areas of which are partially filled with clay, through which water cannot pass: in such a case it is obvious, that the sands beneath the clay, fed by the rain which descends on the uncovered margin of the basin, must constitute a reservoir, and the water gradually accumulate beneath the central plateau of clay, whence it cannot escape. If this bed of clay be perforated, either by natural or artificial means, the water must necessarily rise to the surface, and may be thrown up in a jet to a considerable height, which will depend on the level of the fluid in the subterranean reservoir; such is the phenomenon observable in the

* See my notes on the Geology of Surrey, in Brayley's History of that county.

Artesian wells around London. Argillaceous strata are generally found to be dry within, and the blue clay confines the water contained in the sands beneath ; the engineer therefore perforates the clay, introduces tubes, and taps the natural tank, and the imprisoned waters rush to the surface ; by this method perennial fountains have been formed at Tooting, Hammersmith, Fulham, &c.*

The wells sunk into the London clay (*Lign.* 35, 1, *d*, *d*,) do



LIGN. 35.—PLAN OF THE ARTESIAN WELLS NEAR LONDON.

1. The London clay. 2. Plastic clay and sand. 3 The chalk.

a, b, b, Borings that reach the chalk. *c, c,* Wells in the plastic clay. *d, d,* Wells in the London clay.

not yield pure water ; but the sandy strata alternating with the clays, afford a supply, the quantity and quality of which depend on the nature of the rock. The borings which reach the sands of the plastic clay (*Lign.* 35, 2, *c*, *c*,) furnish good soft-water ; but the wells that extend to the chalk (*Lign.* 35, 3, *a*, *b*, *b*,) obtain the most copious springs, the water often rising to the surface in a perennial fountain.†

* Consult Dr. Buckland's Bridgewater Essay, p. 561 ; and an admirable Essay on Artesian Wells, in the Mining Journal, conducted by H. English, Esq. F. G. S.

† As the white chalk, into which the Artesian borings in London are generally carried some twenty or thirty feet, is not a retentive rock, but on the contrary is so porous that not a natural pool or lake is to be found throughout the chalk districts, except under some peculiar local conditions, a few words must be added, to explain this anomaly. The *chalk-marl,* which is the first retentive bed of any considerable extent in the cretaceous formation, lies at a depth of many hundred feet beneath the bottom of the London basin, and therefore could not, in ordinary conditions, form a reservoir that could be reached by artificial means, if the strata were either horizontal,

The wells in London vary in depth from 100 to 600 feet; but the total thickness of the clay in some places is estimated at nearly a thousand feet. The most remarkable instance of success in obtaining a perennial fountain from a deep source, by the process of boring above described, is the Artesian well at Grenelle, near Paris, which was carried through the entire series of the tertiary and cretaceous strata, down to the green sand; a depth of 1,800 feet! The water rises in a powerful column to the height of thirty feet above the highest part of Paris, and has a temperature of 91° Fahrenheit, being sufficiently hot for warming greenhouses, &c.

25. THE HAMPSHIRE BASIN.—The London basin does not present an alternation of marine and fresh-water deposits, like that of Paris; but in Hampshire and the Isle of Wight, there is an extensive suite of tertiary, composed of fresh-water clays, sands, and limestones, associated with marine strata. This series extends over a considerable district. On the east, a small outlier of the lower beds of plastic clay appears at Castle Hill, near Newhaven, in Sussex;* and to the west of Brighton, the London clay rises to the surface, and forms the subsoil between the Downs and the sea-shore. The inland boundary of these tertiary strata stretches by Chichester, Emsworth, and Southampton, to Dorchester; and the London clay is

or lying inclined in a direction from the central plateau of London; but the chalk forms a deep gulf or excavation, in which the London clay is situated, and thus the drainage from the surrounding chalk hills flows into the centre of the basin, and furnishes an almost inexhaustible reservoir. I need not add, that attempts to obtain water by Artesian borings in any chalk district, where the strata are horizontal or inclined, will fail, unless the beds immediately upon the *chalk-marl* could be reached. The borings for water near South. ampton exemplify these remarks. See my *Geology of the Isle of Wight*, p. 81.

* Geology of the South-East of England, p. 53.

spread over the whole area of the New Forest and the Trough of Poole, being flanked by the chalk on the north, north-east, and north-west, and open to the sea on the south. The Isle of Wight, though now separated from the main land, is a disrupted mass of the formations of the south-east of England ; the chalk basin having been broken up, and the cretaceous strata, with the superimposed sands, clays, and gravel, thrown in many instances into a vertical position. This phenomenon is strikingly displayed at the north-west extremity of the island, at Alum Bay, and in the eastern, at Culver Cliff and Whitecliff Bay.

26. ALUM BAY.—Alum Bay, so called from the alum, formerly extracted from the decomposing pyrites with which the clay abounds, is well known to the visitors of the Isle of Wight. This sketch (*Lign.* 36) conveys a general outline of the bay ; *a*, represents the vertical chalk ; *b*, *b*, the tertiary strata, consisting of sands and clays of an

LIGN. 36.—ALUM BAY, ISLE OF WIGHT; FROM THE WEST.
a, Chalk strata, nearly vertical. *b*, *b*, Vertical Tertiary strata.

infinite variety of colour. The appearance of these cliffs is thus graphically described by Mr. Webster, whose memoir on the strata above the English Chalk, formed a new era in British Geology, and raised our tertiary series to an importance equal to that of the Paris basin.

"The clays and sands of Alum Bay afford one of the most interesting natural sections imaginable. They exhibit the actual state of the strata above the chalk, before any change took place in the position of the latter. For, although the beds of which they are composed are quite vertical, yet, from the nature and variety of their composition, and the regularity and number of their alternations, no one who views them can doubt that they have suffered no change, except that of having been moved with the chalk from a horizontal to a vertical position. These sands and clays present every variety of colour of green, yellow, red, crimson, ferruginous, white, black, and brown."

27. London clay of the Hampshire basin. — The London clay extends over the greater portion of the area of the Hampshire basin, its peculiar fossils abounding in many localities. Castle Hill, near Newhaven, which has been already mentioned as an isolated portion of the lower series of plastic clay, is made up of sands, marls, and clays, with beds of oyster-shells and shingle ; these deposits form the upper part of the hill, and rest upon the chalk of which the lowermost fifty feet of the cliff are composed.* The *subsulphate of alumine*,† a mineral peculiar to this locality, occurs in the ochraceous clay which is in immediate contact with the chalk. Selenite, or crystallized gypsum, abounds in the marls ; and there is a layer of surturbrand, or lignite, a few inches thick, containing impressions of dicotyledonous plants.‡ The clays abound in marine and freshwater shells ; some of the layers being aggregations of compressed shells, held together by argillaceous earth.§ The

* See Geology of the South Downs, p. 261.

† British Mineralogy, Tab. 499. Geology of the South-East of England, p. 56.

‡ Fossils of the South Downs, Pl. viii. figs. 1, 2, 3, 4.

§ Two species of *Potamides*, and one of *Cyclas*, (both fresh-water genera,) are the prevailing forms.

oyster-bed, where pebbles enter into the composition of the concreted masses, closely resembles the Bromley conglomerate (p. 230). I have collected a few teeth of sharks, but no other vestiges of fishes have been observed. At Chimting Castle, near Seaford, on the eastern escarpment of the valley of the Ouse, olive-green sand, and a ferruginous conglomerate of chalk-flints, lie upon the chalk; proving the further eastward extension of the tertiary beds along the Sussex coast.*

To the west of Brighton, the London clay is perceived near Worthing, emerging from beneath the alluvium which, as we have already seen, contains remains of elephants. At Bognor, an arenaceous limestone, full of the usual shells of the London clay,† constitutes a group of low rocks, which in another century will probably have entirely disappeared. The beauty and variety of the shells, particularly of the nautili, and of the perforated fossil wood, render these organic remains objects of considerable interest.

In the blue clay at Bracklesham Bay, on the western coast of Sussex, and at Stubbington, fossil shells may be obtained at low-water in profusion;‡ and Hordwell and Barton Cliffs, in Hampshire,§ have long been celebrated for similar fossils; shells from these localities are to be found in almost every collection of organic remains.

28. Fresh-water tertiary strata of the Isle of Wight.—The peculiarity of the Isle of Wight eocene strata as compared with those of London, consists in the

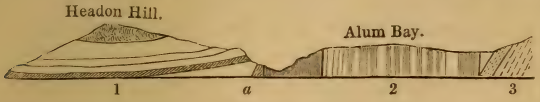
* Geology of the South-East of England, p. 62.

† Fossils of the South Downs, p. 271.

‡ Bracklesham Bay, on the western coast of Sussex, is bounded by a low cliff composed of blue clay, and green sand, full of fossil shells, fishes' teeth, and other remains. For a particular account of this productive tertiary locality, see "*Excursion to Bracklesham Bay,*" in my Medals of Creation, vol. ii. p. 902.

§ These cliffs are fully described in my Geology of the Isle of Wight, chap. v. p. 164.

lacustrine and fluviatile character of the upper series of deposits, which is superimposed on marine strata identical with those of Bracklesham. These fresh-water beds consist of marls, sands, and limestones, containing abundance of river and lacustrine shells, and a few bones and teeth of mammalia, of some of the extinct genera of the Paris basin. This series is spread over the northern districts of the Island, forming the coast-line from White-cliff Bay, to Headon Hill in Alum Bay. The relative position of the fluviatile and marine eocene strata, is shown in *Lign.* 37 : strata, the equivalents of the Bognor rocks,



LIGN 37.—SECTION OF HEADON HILL AND ALUM BAY.

Fig. 1. Fresh-water strata of Headon Hill. 2. Vertical marine strata of Alum Bay. 3. Nearly vertical beds of Chalk.

London clay, Bracklesham clay, and Bagshot sands, appear in a vertical position throughout the entire extent of Alum Bay, from the white chalk (3), to the foot of Headon Hill (*a*); and are succeeded by the fresh-water deposits (1.) The limestones abounding in fluviatile shells (*see Lign.* 39), are quarried at Binstead near Ryde, and at Calbourn, and Shalfleet ; and may be seen in various places along the northern coast. Bones of turtles and crocodilian reptiles, are sometimes met with.*

29. ORGANIC REMAINS OF THE EOCENE STRATA ; FOSSIL PLANTS.—So numerous are the relics of the inhabitants

* These strata, and the most interesting fossils hitherto discovered in the Isle of Wight, are so fully described and illustrated in my recent work, "Excursions round the Isle of Wight, &c.," that I beg to refer to that volume for more ample information.

of the ancient lands and waters entombed in the strata we have thus cursorily surveyed, that I can only offer a very brief account of the organic remains. I will select a few of the fossils of the Paris basin as typical of the zoology of the older tertiary epoch, and notice such others from British localities, as may be requisite for the elucidation of the subject.

Dicotyledonous wood occurs in considerable abundance, in the state of large trunks and branches, which appear to have been drifted far out to sea, and are full of perforations inclosing shells of boring mollusca. The strata around London, and in the Isle of Sheppey, abound in specimens of this kind. Leaves and stems of palms have been found in the Paris basin, and in the Isle of Sheppey, &c.; and the trunk of a tree related to the palm, nearly four feet in diameter, at Soissons. Fruits belonging to trees allied to the Areca, pine, fir, cocoa-tree, &c. have been discovered in several localities. The abundance of fruits of numerous genera belonging to hot climates, that are accumulated in the Isle of Sheppey, has already been mentioned (*ante*, p. 232). Beds of lignite or *brown coal*, occur at Bovey Tracey in Devonshire,* and in various parts of France, the Netherlands, &c.

30. AMBER.—The beautiful substance so remarkable for its electric properties, Amber, is a production of the tertiary epoch, and is highly interesting in a geological point of view, from its containing insects and other organic bodies. The Amber in common use is chiefly obtained from submarine beds of lignite in Prussia, and along the coast of the Baltic; this substance being washed up by the action of the sea, and drifted on the shore. It is a fossil resin, the product of an extinct species of pine (*Pinus succinifer*). Insects, spiders, small crustaceans, leaves, and fragments

* See Medals of Creation, vol. i. p. 84.

of vegetable tissue, are imbedded in some of the masses. Upwards of 800 species of insects have been observed; most of them belong to species and even genera that appear to be distinct from any now known; but others are nearly related to indigenous species, and some are identical with existing forms, that inhabit more southern climes.

The forests of Amber-pines were in the south-eastern part of what is now the bed of the Baltic, in about 55° north latitude, and 37°—38° east longitude. The different colours of amber are derived from local chemical admixture. The amber contains fragments of vegetable matter, and from these it has been ascertained that the amber-pine forests contained four other species of pine, and several Cypresses, Yews, and Junipers, with Oaks, Poplars, Beeches, &c.; altogether forty-eight species of trees and shrubs; constituting a flora of a North American character. There are also some ferns, mosses, fungi, and liverworts.*

31. Zoophytes.—Polyparia, or corals, and other zoophytes, abound in some of the marine strata, but the species are not very numerous in the British series. Several kinds of turbinolia, caryophyllia, fungia, and other corals, are figured and described by authors. I have a few specimens from Grignon, presented to me by the late Baron Cuvier. The modern tertiary (those of Palermo for example) abound in various kinds of flustra and sponges. The coralline strata of the Crag are almost wholly made up of a few forms of *Tubuliporidæ* (p. 224).

An elegant small *Astrea* has recently been found at Bracklesham in Sussex, by Mr. Bowerbank. Some of the tertiary strata of North America abound in corals.†

* Professor Göppert: Geol. Proc. 1845.

† Geol. Journal, No. 4, p. 495; Report on the Corals from the Eocene and Miocene of North America, by Mr. Lonsdale.

32. SHELLS OF THE TERTIARY STRATA.—The shells of the tertiary epoch already determined by naturalists, amount to nearly three thousand. We have seen that some of the strata are almost entirely composed of these remains in a broken and compressed state, and many seams

LIGN. 38.—MARINE EOCENE SHELLS OF THE PARIS BASIN.

Fig. 1. Cypræa inflata. 2. Ancilla canalifera. 3. Fusus uniplicatus. 4. Cerithium lamellosum. 5. Pleurotoma dentata. 6. Lucina sulcata. 7. Ampullaria sigaretina. 8. Pectunculus angusti-costatus.

in the argillaceous beds consist of shell-dust. In some localities the shells are finely preserved; and the calcaire grossier at Grignon, a few leagues from Paris, has long been celebrated for its beautiful fossils; hundreds of eocene species have been collected from one small area. Many of the species also abound in the London and Hampshire basins, as at Highgate, the Isle of Sheppey, Hordwell, Alum Bay, and Whitecliff Bay; and at Bognor and Bracklesham, on the Sussex coast.

I have selected a few specimens from my cabinet, to convey an idea of their usual characters and appearance, (*Lign.* 38). Although, in mentioning the names of these shells, I do not expect that any but the scientific inquirer

LIGN. 39.—FRESH-WATER SHELLS OF THE PARIS BASIN.

Figs. 1, 2. Bulimus conicus. Figs. 3, 4. Cyclostoma mumia. Fig. 5. Limnæa effilea. Figs. 6, 7. Planorbis euomphalus. Fig. 8, Planorbis cylindricus.

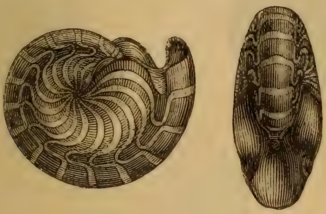
will endeavour to fix them on the memory, yet it may be useful to point out the forms which prevail in these tertiary beds; for, as particular fossils are confined to certain strata, the experienced observer can often, at a glance, determine the relative antiquity of a deposit by an examination of a few species of shells. The whole of these forms must be familiar to you, as they belong to genera which swarm in our present seas. The *Cypræa*, or Cowry (*Lign.* 38, *fig.* 1), and the *Ancilla*, or Olive (*fig.* 2), are well-known types. The *Cerithium* (*fig.* 4), belongs to a genus most abundant in the sands of the Paris basin, and is remarkable for the elegance and variety of the fossil species, which exceed by three times in number their living analogues. The *Cerithium giganteum* attains a considerable magnitude. Some masses of the Bognor rock are almost wholly composed of a species of *Pectunculus*, (*fig.* 8.) The *Ampullaria* (*fig.* 7) is abundant at Grignon, and commonly in a beautiful state of freshness.

It has already been observed, that the shells of fresh-water mollusca possess characters by which they may be distinguished from marine species. This small selection (*Lign.* 39) from the fresh-water beds of Paris will serve to illustrate this remark. The general appearance of these shells will remind you of certain kinds which inhabit our ponds and rivers; particularly the large thin snail (*Limnæa*,* *fig.* 5), and the discoidal shell (*Planorbis*, *figs.* 6, 7, 8); while *figs.* 3 and 4, (*Cyclostoma*,) resemble a species that inhabits the banks of lakes. At Headon Hill, Binstead, Calbourne, &c. in the Isle of Wight, the clays and limestones are full of fresh-water shells.

33. Fossil Nautilus.—Several species of Nautilus are found in the tertiary strata at Highgate, Sheppey, and Bognor; those inclosed in the septaria, or indurated argillaceous nodules, of the London clay, possess considerable beauty, and admit of being cut into sections, which admirably

* The *Limnæa* and *Planorbis* are generally joint inhabitants of our pools and streams. They are pulmoniferous, that is, possess air-breathing organs; hence they are obliged frequently to rise to the surface of the water to respire the air.—See Plate I. of my *Geology of the Isle of Wight:* in that work the name of the first genus is erroneously printed *Limneus*.

display the internal structure of the original. I shall defer an explanation of the mechanism of these shells to the subsequent lecture, when other genera of the same order will come under our notice. The large splendid species (*Nautilus imperialis*) of which hundreds of specimens have been collected from the cuttings at Highgate Tunnel, and the recent railway excavations, is figured in Sowerby's Mineral Conchology ; a work which contains coloured representations of a great number of the British tertiary shells. I will only particularize a rare and elegant species, discovered by Mr. Wetherell, of Highgate, which is here figured of the natural size.



1 2

LIGN. 40.—NAUTILUS ZICZAC, FROM THE LONDON CLAY, PRIMROSE HILL.

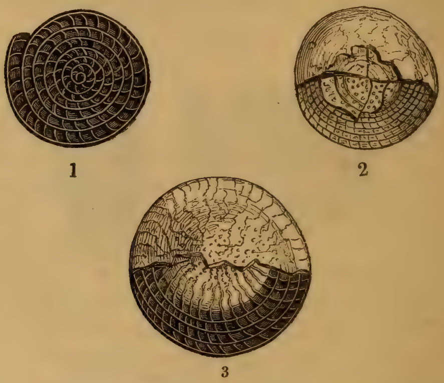
(In the cabinet of Mr. Wetherell.)

Fig. 1. Side view. Fig. 2. Front view.

This shell is remarkable for the peculiar character of the *septa* or divisions, as expressed in the specific name ; the siphunculus extends along the inner margin. The septa are distinctly seen, in consequence of the external layer of the shell having been destroyed by decomposition.

34. NUMMULITES : AND OTHER FORAMINIFERA.—The fossils called *Nummulites* (from their resemblance to a coin) belong to those extremely minute forms of molluscous animals which are termed *Foraminifera*, from the shells of most of the genera being perforated all over with openings or foramina.

The Nummulite, which is the largest of this order, is of a lenticular, discoidal form, and varies in size from a mere point, to an inch and a half in diameter. The outer surface is generally smooth, and marked with fine undulating lines. On splitting the shell transversely, it is found to consist of several coils, which are divided into a great many cells or chambers by oblique partitions (*Lign.* 41, *fig.* 1), having no communication with each other. The specimens which I now place before you (*Lign.* 41), are from the limestone



LIGN. 41.—NUMMULITES, FROM THE GREAT PYRAMID OF EGYPT.

(*Collected by Dr. George Hall, of Brighton.*)

Fig. 1. Horizontal section of a Nummulite. Figs. 2, 3. Nummulites, with the external plate partially removed.

which constitutes the foundation rock of the Great Pyramid of Egypt, and of which that structure is in great part composed. Strabo alludes to the nummulites of the Pyramids, under the supposition that they are lentils which had been scattered about by the workmen, and had become converted into stone. This polished pebble from Egypt, is a silicified mass of nummulites, the markings on the surface being sections of the inclosed shells. The Nummulites are widely diffused through the ancient tertiary deposits, and form entire chains of calcareous hills. They constitute immense beds in the Alps and Pyrenees, and are not confined to the tertiary, but occur also in some of the secondary formations. The blue clay at Bracklesham and Stubbington, and the calcareous sandstone of Emsworth and Bognor, in Sussex, abound in Nummulites.

In North America, the eocene limestone of Suggsville, which forms a range of hills 300 feet in height, is entirely composed of lenticular bodies, supposed to be related to this genus.* In some parts of France, beds of nummulitic limestone of great extent and thickness occur, and are referable either to the lowermost group of the tertiary formations, or the uppermost of the cretaceous.

35. Rotaliæ.—Many of the foraminifera have chambered shells, so like that of the Nautilus, that but for their perforated surface, they might be taken for embryotic cephalopoda. The animals of these polythalamia (many-chambered shells), have, however, no relation whatever to the nautilus, but are of a very simple structure, as we shall explain in the next lecture, when treating of the Rotaliæ of the chalk. These animalcules swarm in many of the tertiary strata; in the annexed sketch (*Lign.* 42) are shown two specimens adhering to a very characteristic shell (*Vermetus*) of the Bognor sandstone. The marine sands of the Paris basin are, in some localities, so full of microscopic forms, that a cubic inch of the mass contains upwards of sixty thousand foraminifera.†

36. Crustaceans and Fishes.—Of the higher order of crustaceans, as the Crabs, Lobsters, &c., many species are

* *Nummulites Mantelli* of Dr. Morton. I have not been able to detect the nummulitic structure in these fossils. See Synopsis of the Organic Remains of the Cretaceous Group of North America. Philadelphia, 1834.

† Medals of Creation, vol. i. p. 221.

found in the London Clay, and other tertiary deposits; the greater number are extinct, or at least unknown to

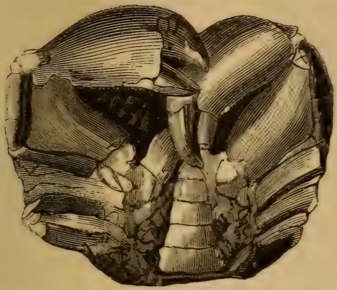
LIGN. 42.—FOSSIL SHELLS, FROM THE LONDON CLAY, AT PRIMROSE HILL.
(Collected and described by Mr. Wetherell.)

Fig. 1. Two specimens of *Vermetus Bognoriensis*; natural size.
2 and 3. Portion of the same magnified, to show more distinctly two minute *Rotaliæ* which adhere to them.
2* Magnified views of the smaller Rotalia, seen in profile, and laterally.
3* The same of the larger specimen.

naturalists. As the external configuration of the shell or crustaceous covering of these animals, is conformable to the soft parts it incloses and protects, the form and size of the principal viscera, as the heart, stomach, &c. may be ascertained from the markings impressed on the case; and thus the character of a fossil species, and its relation to living types, may be determined by the experienced zoologist, from an examination of the carapace and other parts of the shell. Many very beautiful fossil crabs and lobsters have been collected from the clay in the Isle of Sheppey;* some of which are figured and described by Mr. Parkinson,† and M. Brongniart.‡ In the tertiary

* Medals of Creation, vol. ii. p. 530.
† Organic Remains of a Former World, vol. iii.
‡ Histoire Nat. Crust. Foss. pl. viii. figs. 5 and 6.

limestone of Malta a species of Crab occurs in great perfection, as exemplified in the specimen before us (*Lign.* 43). The minute crustaceans, termed *Cyprides*, which swarm in our pools, lakes, and streams of fresh water, are abundantly distributed in some of the tertiary fluviatile deposits.*



LIGN. 43.—FOSSIL CRAB, FROM MALTA—(*half the natural size*).
(*Cancer Macrochelus.*)

Fishes of the Tertiary Epoch. The fishes that have been collected from the various groups of tertiary strata, comprise many hundred species, belonging to all the existing orders and families; but some of the most ancient forms either do not occur, or are but feebly represented.† Nearly two hundred species are figured and described by M. Agassiz in his splendid work on fossil fishes; of which between forty and fifty belong to the universally distributed family, the Sharks. Teeth of various genera of this voracious tribe, are found in abundance in numerous British localities.‡ In the Crag, teeth of enormous size (*Carcharodon*) are often met with; and the same species occurs in the tertiary of Maryland. The teeth of several genera of

* Medals of Creation, vol. ii. p. 119.

† See Genealogical table of the class Fishes, in M. Agassiz's "*Recherches sur les Poissons Fossiles.*"

‡ Medals of Creation, vol. ii. p. 623.

the Ray family, abound in the clay of Bracklesham, Hordwell, and the Isle of Sheppey. The jaws, covered with their dental plates, or teeth, of several species of the Eagle-rays* (*Miliobatis*) occur in the same localities: and the maxillary bones, with their tubercles, of those extraordinary fishes, the *Chimæroids*, have been found in a remarkably fine state of preservation, at Bracklesham Bay, Highgate, Isle of Sheppey, &c.†

The swarms of fishes in the strata of Monte Bolca, and at Aix in Provence,‡ have been already alluded to: and our limits will not admit of a more extended notice; but I may add, that a gigantic *Torpedo* has been discovered at Monte Bolca. The only existing species of fish known in a fossil state is the little *Mallotus villosus*, which inhabits the shores of Iceland, of which fossil specimens occur in nodules of indurated marl or clay, along the coasts of that island.§

As a concise expression of the Ichthyology of the tertiary epoch, it may be stated that the fossil fishes approach in their characters to the living genera, but all the species are extinct. The newer tertiary, as the Crag, contain genera common in tropical seas, as the large sharks (*Carcharias*) and Eagle-rays, &c. In the eocene or most ancient, as the London and Paris basin, Monte Bolca, &c., one third of the Ichthyolites belong to extinct genera.||

37. Reptiles of the Tertiary epoch.—The reptiles of the Tertiary, like the mammalia, fishes, and other classes of animals, more nearly approach the recent types, than the fossil reptilians of the more ancient strata. All the orders now existing have representatives in the deposits of this epoch. In the London Clay, remains of Alligators, Crocodiles, and Serpents, have been found in many localities; and of the Turtles or Chelonians, detached bones of terrestrial

* Medals of Creation, vol. ii. p. 629.
† Ibid. p. 619.
‡ Ibid. p. 587.
§ Ibid. p. 670.
|| Ibid. p. 670.

Tortoises, and fresh-water and marine Turtles ; many entire specimens of the carapace and plastron, have been obtained from Sheppey, and Harwich. Some beautiful examples have also been met with in the Isle of Wight.* The lower jaw of an Alligator (*A. Hantoniensis*) with the teeth, was found in Hordwell Cliff;† and in the clay near Lymington I discovered many bones of a crocodile (*Crocodilus Spenceri*) :‡ Lady Hastings has obtained a perfect skull, and other parts of the skeleton of a Crocodile, from the same locality.

LIGN. 44.—FOSSIL BIRD, FROM MONTMARTRE.

In the eocene strata of India, Dr. Falconer found, with the colossal tortoise (p. 164), bones of other tortoises, and gavials, that could not be distinguished from those of species now inhabiting India. The lacustrine deposit of Œningen (p. 263), has yielded specimens of a large extinct species of Salamander.

38. FOSSIL BIRDS. — In the gypseous building-stone of Montmartre, M. Cuvier found many bones possessing characters peculiar to those of birds ; and after much research he was enabled to determine several fossil species, related to the pelican, sea-lark, curlew, woodcock, buzzard, owl, and quail. In some examples there are indications of the feathers,

* Geology of the Isle of Wight, p. 112.

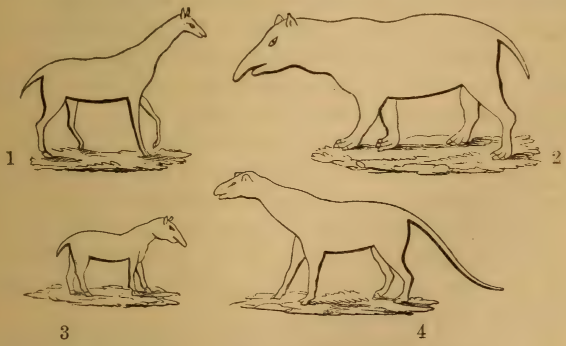
† London Journal of Geology and Palæontology, plate 2.

‡ Geology of the Isle of Wight, p. 163.

and even of the air-tubes. Sometimes the skeleton is wanting, and a pellicle of a dark brown substance alone points out the configuration of the original (*Lign.* 44). Not only are the skeletons and feathers of birds found in the tertiary strata, but even the eggs of aquatic species occur in the lacustrine limestone of Auvergne; these have probably been formed in loose calcareous debris along the borders of the lakes, in like manner as the eggs of turtles incrusted in the modern travertine, on the shores of the Isle of Ascension (p. 90).

39. Fossil mammalia of Paris.—We have next to consider the fossil remains of the mammalia, whose skeletons were entombed in the mud of the waters which formerly occupied the site of the metropolis of France, and the surrounding country. The gypsum quarries which are spread over the flanks of Montmartre had long been known to afford fossil bones; but though specimens occasionally attracted the notice of the naturalists of Paris, and collections were formed, no one appears to have suspected the mine of wonders which the rocks contained, till the curiosity of Baron Cuvier was awakened by the inspection of a large collection of these bones, after he had successfully applied the laws of comparative anatomy to the investigation of the fossil elephants and mammoths. He had previously paid but little attention to the partial accounts of fossil bones found in the vicinity of Paris, although in 1768, M. Guettard had figured and described many bones and teeth.

M. Cuvier now, however, perceived that a new world was open to his researches, and he soon obtained an extensive collection, and found himself, to use his own expression, in an ancient charnel-house, surrounded by a confused mass of mutilated skeletons of a great variety of animals. To arrange each fragment in its proper place, and restore order to these heterogeneous relics, seemed at first a hopeless task; but a knowledge of the immutable laws by which the organization of animal existence is governed, soon enabled him to assign to each bone, and even fragment, its proper place in the skeleton ; and the forms of beings hitherto unseen by mortal eye arose before him. "I cannot," exclaimed the illustrious philosopher, in all the enthusiasm of successful genius, "express my delight on finding how the application of one principle was instantly followed by the most triumphant results. The essential character of a tooth, and its relation to the skull, being determined, immediately all the other elements of the fabric fell into their proper places ; and the vertebræ, ribs, bones of the legs, thighs and feet, seemed to arrange themselves even without my bidding, and precisely in the manner which I had predicted." The principles of comparative anatomy enunciated in the previous lecture will have prepared you for this result ; and I need not dwell on the application of the laws of correlation of structure by which the animals



LIGN. 45.—ANIMALS OF THE TERTIARY EPOCH.

Fig. 1. Anoplotherium gracile. 2. Palæotherium magnum. 3. P. minus. 4. Anoplotherium commune.

of the Paris basin have been brought to light. This group of figures (*Lign.* 45) from Cuvier's restorations, is indeed a splendid achievement of Palæontology.

The examination of the fossil teeth at once showed that the animals were herbivorous, the enamel and ivory being disposed in the manner already explained (p. 141); the crown of the tooth is composed of two or three simple crescents, as in certain pachydermata; thus differing from the ruminants, which have double crescents, and each four lines of enamel. Following out the inquiry, Cuvier at length ascertained that a great proportion of the bones and teeth, belonged to two extinct genera of pachyderms, related to the tapir, rhinoceros, and hippopotamus.

Every one is familiar with the forms and habits of the two last animals; but the Tapirs are not so well known; they are a family of pachyderms confined to Sumatra and South America. The Malay Tapir, a stuffed specimen of which may be seen in the British Museum, sometimes attains eight feet in length, and six in circumference. It has a flexible proboscis, a few inches long; its general appearance is heavy and massive, resembling that of the hog. The eyes are small, the ears roundish; the skin is thick and firm, and covered with stout hair, and the tail short. It inhabits the banks of lakes and rivers, and has been observed to walk under water, but never to swim.

40. PALÆOTHERIA, AND ANOPLOTHERIA.—It is unnecessary to enter at large on the structure and habits of the animals to which these remains belonged; for even the forms of these extinct beings must be familiar to the reader, as Cuvier's restorations of their living lineaments, are to be found in every popular work that treats of the ancient inhabitants of our globe.

The *Anoplotheria* are remarkably distinguished by having feet with but two toes, as in the ruminants, and are the most ancient form of bi-hoofed animal known in a fossil state. They had an uninterrupted dental system, the teeth being placed in a continuous series, as in man, without any interval between them. The *A. commune* (*Lign.* 45, *fig.* 4), was eight feet long, and of the height of a wild boar, but of a more elongated shape ; it had a long and thick tail, which must have enabled it to swim with facility, like the Otter ; the structure of the teeth indicates that it browsed on grass like the horse. The *A. gracile* (*Lign.* 45, *fig.* 1), so named from its elegant proportions, was of the size and form of the Gazelle, and must have lived after the manner of the deer and antelopes.

The *Palæotheria* resembled the Tapirs in the form of the head, and in having a short proboscis, but their molar teeth were more like those of the Rhinoceros ; their fore-feet had but three toes, instead of four as in the Tapirs. Upwards of eleven species, varying from the size of the Rhinoceros to that of the Hog, have been discovered in the tertiary strata of France. The *P. magnum* (*Lign.* 45, *fig.* 2), was of the magnitude of a horse four or five feet high, with a massive head and proboscis, and short extremities. The *P. medium* was one-sixth smaller than the American Tapir, but had longer and slighter legs and feet. The *P. minus* (*fig.* 3) was an elegant creature as large as the Roebuck, with light and slender limbs.

Numerous other genera of extinct mammalia have been discovered in the eocene strata, and their characters determined by Baron Cuvier. Some are related to the animals we have just described ; as the *Anthracotherium*, (so named from the discovery of its remains in the anthracite, or lignite of Cadibona,) which held an intermediate place between the hog and hippopotamus. Six or seven species of carnivora, an opossum, a squirrel, dormouse, &c. have also been found in the Paris basin. In England, remains of several species of Palæotheria, Anoplotheria, and other characteristic genera, have been discovered.*

In the miocene strata of Touraine and of Darmstadt,

* See Prof. Owen's British Fossil Mammalia ; and my Geology of the Isle of Wight, p. 115.

remains of the above extinct mammalia, and of the mastodon, are found associated with those of existing genera.

41. Fossil Monkeys.—The illustrious Cuvier, when commenting on the extraordinary fact, that among the innumerable relics of the mammalia which peopled the continents and islands of our planet during the tertiary ages, no traces of man or of his works occur, emphatically observed, that it was a phenomenon not less surprising, that no remains of the quadrumanous tribes, which rank next

1 2 3

Lign. 46.—Portion of the lower jaw of a Monkey; from eocene sand at Kingston, near Woodbridge.*

(Magnified two diameters.)

Fig. 1.—The outer side of the tooth and jaw.
2.—View of the specimen from above, showing the upper surface of the crown of the tooth.
3.—View of the inner side.

to the human race in physical conformation, should have been discovered; and that the circumstance was the more remarkable, because the majority of the mammalia found in the drift, and tertiary deposits, have their congeners at the present time in the warmest regions of the globe; in those intertropical climates where the existing quadrumana

* From the Magazine of Nat. Hist. vol. iii. p. 447.

are almost exclusively located.* At length proofs were obtained, and almost at the same time in France, India, South America, and England, of the existence of this order of animals during the most ancient tertiary epochs.

The fossil remains are referable to four modifications of the existing types of quadrumana. Those from France belong to an animal of the Ape tribe; those from England to the *Macacus;* the Indian fossils to a species of the long-limbed and tailed monkeys, of which the Negro monkey is an example; and the relics from South America to a gigantic Capuchin monkey.†

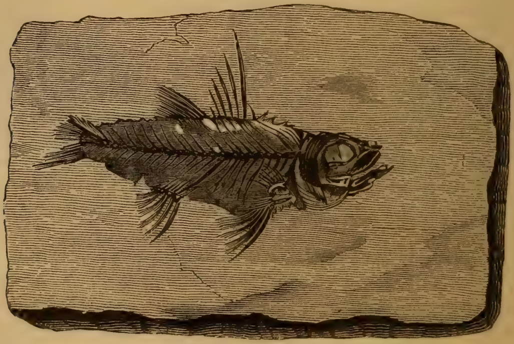
The British specimens (*Lign.* 46), were found in a bed of eocene sand, at Kyson or Kingston, a few miles east of Woodbridge in Suffolk.‡

* Discours sur les Révolutions, p. 171.

† THE QUADRUMANA OR MONKEYS.—These animals come nearest to man in the form and proportion of their skeleton, and of their separate bones; in the general disposition of their muscular system, and its adaptation for a semi-erect position of the body; in their great cerebral organization, the perfection and equable development of their senses; their intellectual capacity, and complicated instincts. These most elevated of all inferior animals are fitted to select, obtain, and digest the succulent ripe fruits of trees, and are destined to inhabit the rich and shady forests of tropical climates. They leave to the squirrels and the sloths the buds and leaves; to the ponderous elephant and rhinoceros the branches and the stem; and to the beavers, and other rodentia, the hard bark of the trees. Their delicate organization is adapted only for the richest products of the vegetable kingdom; and the soft and nutritious quality of their food is suitable to the broad enamelled crowns of their molar teeth, which are studded with rounded tubercles: their stomach is simple. With a high cerebral and muscular development, corresponding with their elevated rank in the scale of beings, and the position of their food, they are the most agile and sportive of all mammalia; and they are provided with prehensile organs at every point; their teeth, tail, feet, and hands assist in their agile movements, and in their boundings from branch to branch, and from tree to tree.—*Dr. Grant's Lectures on Comparative Anatomy.*

‡ See Prof. Owen's British Fossil Mammalia, and my Medals of Creation, vol. ii. p. 863.

42. TERTIARY STRATA AT AIX.—A group of strata remarkable for its organic remains, occurs near Aix, a town in Provence, which is situated upon a thick deposit of tertiary conglomerate. The series on the northern side of the valley consists of—1. Tertiary breccia, the lowermost bed, which forms the site of the town of Aix. 2. Marl, with fishes and insects. 3. Gypsum and gypseous marls, containing fishes and insects, leaves of palms, and other plants, and fresh-water univalve and bivalve shells, particularly a species of *cyclas*, in great abundance.* 4. Fresh-water limestone. To the south, extending towards Toulon, are lacustrine strata of red marl, with compact limestone



LIGN. 47.—FOSSIL FISH, FROM AIX.

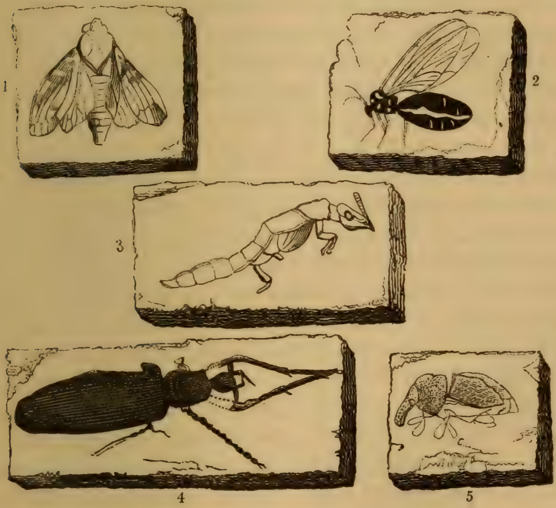
(Smerdis minutus.)

inclosing shells, gyrogonites, &c ; still farther to the south, beds of grey fresh-water limestone appear ; and at Fuveau, a series of blue limestones, shales, and coal, is extensively worked. Fresh-water shells, and seed vessels of *Charæ* with other vegetable remains, occur in abundance in the coal-beds and intermediate layers of shale.

* The *Cyclas* inhabits lakes and marshes, and therefore denotes the lacustrine origin of the deposits.

The marls are finely laminated, and contain insects and fishes in a remarkable state of preservation. The fishes are very numerous; one small species, especially, (*Smerdis minutus*, *Lign.* 47,) which occurs in shoals, and is found grouped in every variety of position.

43. Fossil insects.—But the most extraordinary relics are the fossil insects, which appear as fresh as if enveloped



Lign. 48.—Fossil insects from the tertiary strata at Aix, in Provence.

Fig. 1. *Tettigonia spumaria*. 2. *Mycetophila*, imbedded while in the act of walking; the articulations of the body distended by pressure. 3. *Lathrobium*. 4. Allied to *Penthetria holosericea*. The hinder legs are broken off, and one of them is reversed, so that the *tarsi* nearly touch the thigh; the *palpi* are long and perfect; the *antennæ* remarkably distinct. 5. *Liparus*, resembling *L. punctatus*.

but yesterday. A few of the most interesting forms are here delineated (*Lign.* 48), on a slightly enlarged scale, from the plate accompanying a memoir "On the Freshwater

Formation of Aix, in Provence," by Mr. Lyell, and Sir R. I. Murchison.*

All the insects belong to existing genera, and only one species is aquatic.† The anterior *tarsi* are generally obscure, or distorted ; but in some specimens the claws are visible, and the sculpture, and even a degree of local colouring, are preserved. The nerves of the wings in the *Diptera*, and the pubescence on the head, are distinctly seen. Several of the beetles have the wings extended beyond the *elytra*, as if they had fallen into the water while on the wing, and had made an effort to escape by flight. M. Marcel de Serres has enumerated nearly seventy genera of insects, and a few *Arachnides*, or spiders. The most curious fact is, that *some of the insects are identical with species which now inhabit Provence.* It seems probable that these insects were brought together from different localities by floods, and mountain streams ; yet, as Mr. Curtis observes, all of them might have inhabited moist and shady forests. The laminated marls contain also the coverings of the fresh-water crustacean, called *Cypris*, which swarms in our pools and stagnant waters, and must be familiar to all who have seen the exhibition of the oxy-hydrogen microscope ; living cyprides being commonly shown, and appearing somewhat like the head and feet of a flea protruding from an oval case or shield, and swimming by means of their fine *cilia*, which resemble pencils of hair. These crustaceans shed their cases annually, and the surface of the mud spread over the bottoms of lakes is often covered with their relics. The marls of Aix, as well as of many other fresh-water formations, abound in fossil *Cyprides*, which oftentimes constitute entire seams or thin layers.

The seed-vessels of the *Chara*, a common plant in our ditches and ponds, also occur in profusion ; they were

* Jameson's Edinburgh Journal, for 1829.

† Principles of Geology, vol. iii. p. 211.

formerly supposed to be shells, and from their peculiar structure received the name of *gyrogonites*, which they still bear, although their real nature has long since been ascertained.* In conclusion, Mr. Lyell observes, "that this tertiary series differs essentially from that of the London and Paris basins. The great development of regular beds of blue limestone and shale, the quality and appearance of the coal, and the thickness of the compact grey, brown, and black argillaceous limestones and sandstones, give them the aspect of the most ancient of our secondary rocks; and it is only by the peculiar species of fluviatile and lacustrine shells, the seed-vessels of the charæ, &c. that the comparatively recent date of the whole group is demonstrated."

44. Fossil fox of Œningen.—Among the tertiary lacustrine formations of the Continent, there is one so much celebrated for its organic remains as to require a passing notice. Œningen, near Constance, has for centuries been known to contain fossil remains of great beauty and interest. A short but graphic memoir by Sir R. Murchison,† presents in a few lines the history of this ancient lake. The Rhine, in its course from Constance to Schaffhausen, flows through a depression of a tertiary marine formation, known by the name of *Molasse*, which forms hills on both sides of the river, of from 700 to 900 feet in height. In a depression or basin of this molasse, is a series of strata composed of marls, and cream-coloured, fine-grained, fetid limestone, with laminated white marl-stone, forming a total thickness of thirty or forty feet. In the marl-stone, leaves and stems of plants, insects, shells, crustacea, fishes, turtles, a large aquatic salamander, birds, and a perfect skeleton of an animal allied to the common Fox, have been

* See Medals of Creation, vol. i. p. 187; or Geology of the Isle of Wight, p. 109.

† Geological Transactions, 1832, vol. iii. p. 277.

discovered. This last fossil was purchased by Sir R. Murchison, for whom I developed it, and removed the stone with which all the bones were thickly encrusted, so as to expose the entire skeleton, which differs but slightly from that of the recent species ; it is figured and described in the Geological Transactions for 1832.*

A tortoise, three feet in length, with the cranium and bones of the neck, tail, and of three of the pats, well preserved, has since been discovered. Sir R. Murchison concludes

* Although there were certain obvious differences between some parts of the skeleton, and the corresponding bones of the existing species of Fox with which I had the means of instituting a comparison, I did not feel myself warranted in affirming the fossil to be specifically distinct from all known recent vulperine forms; an opinion in which Mr. Clift entirely concurred; I therefore simply designated it the *Fossil Fox of Œningen.* M. Meyer, however, from my figures and descriptions only, has deemed it right to impose the name of *Canis palustris*; and subsequently Professor Owen, from detecting a few slight discrepancies upon a rigorous comparison of the fossil with recent congenerous forms, has referred it to a new genus; and the fossil, which cost me so many nights of patient dissection to develop, is now enrolled in the annals of science as the *Galecynus Œningensis* of *Prof. Owen.* See Geol. Journal, vol. iii. p. 55. It has been shrewdly remarked, by a celebrated anonymous author, that such is palæontological refinement now-a-days, that an extra plication of enamel in the tooth of a fossil pachyderm, or an additional notch on the tooth of a carnivore, is sufficient to obtain a specific and even sub-generic name for that animal, and constitute its origin a *separate creation!* If this be admitted, the fixity of species must soon be deemed a chimera.

A late eminent naturalist observed, "that the laws of correlation, though so admirable in the results of their application to extinct forms, must still be admitted with great caution, and some limitation: for the proportions of many animals vary greatly, from age and other circumstances. Thus, the legs of a colt are relatively much longer than those of the adult horse; and were we to conclude from the extreme size of the internal condyle of the arm-bone of the *Orycteropus*, that the claws of that animal are equally developed with those of others of the same order, the conclusion would be erroneous."—*Harlan's Medical and Physical Researches*, Philadelphia, 1835.

that these fresh-water deposits are the contents of a lake, belonging to the newer tertiary epoch ; and that the period of their formation must have long preceded the present condition of the country, for they contain some unknown species of animals, and the Rhine has worn a channel through them to the depth of several hundred feet.

45. Fossil fishes of Monte Bolca.—Another interesting assemblage of tertiary strata is exposed in the celebrated quarries of Monte Bolca, that are situated on the borders of the Veronese territory, about fifty miles NN.W. of the lagunes of Venice. These deposits form part of a range of hills of moderate elevation ; volcanic deposits abound in the neighbouring Vicentin, and the summit of the hill at Monte Bolca is capped with basalt.* This hill is principally composed of argillaceous and calcareous strata, with beds of a cream-coloured fissile limestone, which readily separates into laminæ of moderate thickness, and abounds in fishes in the most beautiful state of preservation. They are all compressed flat, but the scales, bones, fins, and even the muscular tissue remain; their colour is a deep brown, thus admirably contrasting with the limestone in which they are imbedded. Several hundred species are contained in these quarries, and thousands of specimens have been collected ; according to M. Agassiz, all the species, though related to the recent, are extinct.† From the immense quantities which occur in so limited an area, it seems probable that the limestone in which they are imbedded was erupted into the ocean in a fluid state by volcanic agency ; and that the fishes were thus suffocated, and surrounded by the calcareous mass. Nor is this hypothesis without support, for on the appearance of a volcanic island in the Mediterranean, a few years since, hundreds of dead fishes were seen putrid and floating in the waters ; and it

* Organic Remains of a Former World, vol. iii. p. 247.

† See Recherches sur les Poissons Fossiles.

cannot be doubted that shoals of fishes may at the same time have been enveloped in the volcanic matter at the bottom of the sea, and become compressed and preserved; and when the mud which envelopes them is consolidated, and the bed of the Mediterranean elevated above the waters, these fishes may resemble the ichthyolites of Monte Bolca.*

46. Tertiary volcanoes of France.—In the former lecture I alluded to volcanic action as still in activity, and as having been equally energetic in more ancient periods; and there is abundant proof, that during the immense lapse of time comprehended between the earliest and the latest of the tertiary formations, the internal fires of our globe were not dormant. We have already had occasion to remark how rarely the former geographical relations of a country are preserved, and that though we may be able to pronounce with certainty that this spot was once dry land,—that yonder flowed a river,—that here is the bed of an ancient sea,—yet we can seldom determine the limits of the one, or trace the boundaries of the other. But there is one remarkable exception—a district, where the most striking geological revolutions have taken place, and yet the area of those changes still maintains its ancient physical geography—that district is Auvergne, a province in central France.

Nearly a century since, two French academicians, MM. Guettard and Malesherbes, on their return from an exploration of Vesuvius, arrived at Montelimart, a small town on the left banks of the Rhone, where Faujas St. Fond, a distinguished naturalist, was sojourning. These savans were struck with the remarkable character of the pavements of the streets, which were formed of short joints of basaltic columns, placed perpendicularly in the ground; and upon inquiry they found the stones had been obtained from the

* See Lecture VIII.

neighbouring mountains of the Vivarais. This information induced them to survey the country; and upon arriving at Clermont, the capital of Auvergne, a town with about 30,000 inhabitants, they were satisfied that the whole region was of volcanic origin; for in the vicinity of that town they discovered consolidated currents of lava, black and rugged as those of Italy, extending uninterruptedly into the plains below, from some conical hills of scoriæ, which still preserved the form of craters.* "To those who now visit central France, and see everywhere unequivocal marks of volcanic agency,—the numerous hills formed entirely of loose cinders, porous and diversified as if just thrown from a furnace, and surrounded by plains of rugged lava, on which even the lichen refuses to vegetate,—it appears scarcely credible, that previously to the last half century, no one had thought of attributing these marks of desolation to the only power in nature capable of producing them. This, however, is perfectly natural, and not without examples. The inhabitants of Herculaneum and Pompeii built their houses with the lava of Vesuvius, ploughed up its scoriæ and ashes, and ascended its crater, without dreaming of their proximity to a volcano which was to give the first proof of its energies by burying them beneath its eruptions; and the Catanians regarded as a fable all mention of the former activity of Etna, when, in 1669, half their town was overwhelmed by its lava currents."†

* Recherches sur les Volcans éteintes du Vivarais: par M. Faujas St. Fond. Paris, 1778.

† Geology of Central France, by G. Poulett Scrope, Esq. F.R.S., 1827. In 1815, Professor Playfair visited Auvergne, and concisely, but graphically, described the volcanic phenomena there exhibited. Mr. Bakewell, in 1823, drew attention to this remarkable district in his "Travels in the Tarentaise, by Robert Bakewell, Esq." 2 vols. 8vo. 1823; and subsequently Dr. Daubeny, Messrs. Scrope, Lyell, and Murchison, have severally published highly interesting memoirs on the geological phenomena of Auvergne.

47. Extinct volcanoes of Auvergne. (Plate II.)—The country which is the site of these extinct volcanoes is about 220 miles south of Paris, and forms a vast plain, situated in the department of the Limagne d'Auvergne. It is so remarkable for its fertility, that it is called the Garden of France ; a quality attributable to the detritus of the volcanic rocks, which enters into the composition of the soil. It is inclosed on the east and west by two parallel ranges of gneiss and granite. Its average breadth is twenty miles, its length between forty and fifty, and its altitude about 1,200 feet above the level of the sea. The surface of this plain is formed of alluvial deposits, composed of granitic and basaltic pebbles, and boulders, reposing on a substratum of limestone. Hills, of various elevations, composed of calcareous rocks, are scattered over the plain ; and the river Allier flows through the district, over beds of limestone and sandstone, except where it has excavated a channel to the foundation-rock of granite. The hills formed of calcareous alluvial deposits, are the remains of a series of beds, which once constituted an ancient plain, at a higher elevation than the present. Many are surmounted by a crest or capping of basalt, to which their preservation is probably attributable ; others have escaped destruction from being protected by horizontal layers of a durable limestone, which I shall presently describe.

We have, then, as the ground-plan of the district, an extensive plain, chequered with low hills of fresh-water limestone, which are capped with compact lava (*Pl.* II. *fig.* III); the boundaries of this tract being formed of ranges of primary rocks, 3,000 feet in altitude. To the westward the limestone disappears, and a plateau of granite rises to a height of about 1,600 feet above the valley of Clermont, being 3,000 feet above the level of the sea. This supports a chain of volcanic cones and dome-shaped mountains, (*Pl.* II. *fig.* II.) about seventy in number, varying in altitude from 500 to 1,000 feet from above their bases, and forming an irregular range nearly twenty miles in length, and two in breadth. The highest point of this range is the Puy* de Dome, which is 4,000 feet above the level of the sea (*Pl.* II. *fig.* II), and is composed entirely of volcanic matter; it possesses a regular crater, 300 feet deep, and nearly 1,000 feet in circumference. Many of these cones retain the form of well-defined craters, and their lava currents may be traced as readily as those of Vesuvius. The Puy de Pariou is a most perfect example: it is a cone covered with fine turf, both on the ascent and within the crater; the latter is a mile in circumference, and very deep, sloping downwards at an angle of 30°. From the lower part of the cone a current of lava, which is still rugged and black, has issued; and the plain is covered with scoriæ and volcanic cinders, which are exposed to the depth of twenty feet, in the ravines made by the winter torrents.

48. Crater of Puy de Come.—One of the most remarkable cones is the Puy de Come, which rises from the plain to the height of 900 feet; its sides are covered with trees, and its summits present two distinct craters, one of which is 250 feet in depth. A stream of lava may be seen to have issued out from the base of the mountain, which at a short distance, from having been obstructed by a mass of granite, has separated into two branches; these can be traced along the granitic platforms, and down the side of a hill into an adjacent valley, where they have dispossessed a river of its bed, and constrained it to work out a fresh channel between the lava and the granite of the opposite bank. Another cone rises to the height of 1,000 feet above the plain, having a crater nearly 600 feet in vertical

* *Puy* is the name given in this province to an insulated conical hill.

depth, and a lava current, which first falls down a steep declivity, and then rolls over the plain in hilly waves of black and scorified rocks. In one part of this volcanic group is a circular system of cones, apparently the produce of several rapidly succeeding eruptions. "The extraordinary character of this scene impresses it for ever on the memory; for there is, perhaps, no spot, even among the Phlegræan fields of Italy, which more strikingly displays the characters of volcanic desolation.* Although the cones are partially covered with wood and herbage, yet the sides of many are still naked; and the interior of their broken craters, rugged, black, and scorified, as well as the rocky floods of lava with which they have loaded the plain, have a freshness of aspect, such as the products of fire alone could have so long preserved, and offer a striking picture of the operation of this element in all its most terrible energy."† The accompanying sketches‡ will illustrate these remarks.

Plate II. *fig*. III. A view of the environs of Clermont. In front is a basaltic peak, crowned by the Castle of Montrognon; and beyond are basaltic platforms (indicated by the dark lines of shade) on hills of limestone. The town is seen in the plain or basin, which has been excavated by diluvial agency, since the deposition of the strata which form the surrounding hills. In the distance is the primary escarpment, forming part of the boundary of the volcanic district.

Fig. II. Part of the southern volcanic chain of Puys, exhibiting the broken craters of Chaumont; from the bases of several the cooled lava currents still remain as when they issued. Mont Dome appears in the distance.

* Plate II. represents a part of this chain of extinct volcanic rocks; with Mont Dome in the distance.

† Scrope's Geology of Central France.

‡ The delineations are reduced from the elaborate and beautiful drawings of Mr. Scrope.

This region affords, too, a striking illustration of the erosion of the surface of a country by alluvial action. The thickness of the volcanic mass is between 300 and 400 feet; it is composed of two distinct beds of basalt, separated by a layer of scoriæ and volcanic fragments. Many portions, both of the upper and lower beds, are made up of well-defined, vertical, polygonal columns. The streams of lava to which these plateaux belong, have been traced for more than thirty miles; they rise in a narrow ridge across the primitive heights, and then spread over, and lie comformably upon, the secondary formations. The limestone beneath the basalt is, in some places, covered with vegetable soil, containing a common species of terrestrial shell (*Cyclostoma elegans*). The nearly horizontal disposition of the basalt, its columnar structure, and position on the limestone, into which it has injected veins and dikes, render it, as Mr. Scrope observes, very analogous to the ancient volcanic rocks of Ireland, which will be described in a future Lecture.

49. Mont Dore (*Pl.* II. *fig.* I). In the same province there is another remarkable system of extinct volcanoes connected with the Puy de Dome. While in the district I have just described, the primitive soil is only partially obscured by the volcanic products, in Mont Dore, the granitic foundation, over an area of many miles in extent, is entirely covered by them, and the erupted masses attain a considerable elevation. Mont Dore is a mountainous tract, the highest portion of which is about 6,000 feet in altitude.* It consists of a group of seven or eight rocky summits, which form a zone a mile in diameter, the whole consisting of a succession of beds of volcanic origin. It is deeply channelled by two principal

* Pl. II. fig. I. is a profile of Mont Dore as seen from a distance, from a sketch by M. Constant Prevost: the dotted outline shows the form of the cone when in activity; a ground plan of the broken crater is annexed.

valleys, and furrowed by many minor water-courses, all originating near the central eminence, and diverging towards every point of the horizon. The beds of which this group is composed, consist of scoriæ, pumice-stone, trachyte, and basalt; these rocks dip off from the central axis, and lie parallel to the sloping flanks of the mountain, as is the case in Etna, the Peak of Teneriffe, and all other insulated volcanic mountains. There is no crater; all vestiges having been destroyed since the extinction of its fires; but streams of lava may be traced, in elevated peaks, over a gorge which occupies the very heart of the mountain, and they extend to a distance of many miles. A remarkable natural section, worn by a cascade, at a short distance from the baths of Mont Dore, exhibits the following beds in a descending series:

1. Porphyritic trachyte; a volcanic rock, 160 feet in thickness. 2. Arenaceous tufa. 3. Columnar basalt. 4. Breccia, made up of volcanic fragments, cemented together by tufa. 5. Thick beds of basalt. 6. White ferruginous tufa, enveloping fragments of granite, basalt, &c., and traversed by veins of the overlying basalt.

I may add, that the volcanic vents of central France are evidently of very different ages; some being of immense antiquity, while others are of comparatively recent origin, for they have exploded through the oldest beds of basalt; but even the most modern belong to a very remote period.

50. Fresh-water strata of Auvergne.—This district presents a series of alternations of fresh-water limestones, with basalt, scoriæ, and other volcanic productions, based on a foundation of granite and gneiss. These beds occur in the following order, beginning with the lowest or most ancient:—

1st. Clay, sand, and breccia, without organic remains.

2d. Limestone and calcareous marl, in strata nearly horizontal; about 900 feet thick. These are entirely of fresh-water origin, for they abound in shells of the genera *potamides, helix, planorbis,* and *limnæa,* which are known to inhabit lakes and rivers. Some of the beds contain bitumen; others are entirely made up of the cases of the Caddis-worm (*Indusia tubulata*), cemented together by calcareo-siliceous matter. (This specimen, which was in the cabinet of Faujas St. Fond, displays the characters of this remarkable concrete: it consists of the tubes or cases of the larvæ of a species of *phryganea*, or may-fly.) These cases, which are formed by the adhesion of shells to the outer surface of the silken case secreted by the insect, are abandoned by the animal when its metamorphosis is completed, and layers of them may often be seen in our ditches and lakes. The fossil cases have been cemented together by calcareous infiltration, and form a compact stone, which is employed for building. The attached shells are so minute, that often more than a hundred are affixed to a single case; and a cubic inch of the limestone includes ten or twelve tubes. If, says Mr. Scrope, we consider that repeated strata, of five or six feet in thickness, almost entirely composed of these fossils, once extended over the whole plain of the Limagne, occupying a surface of many hundred square miles, we may have some idea of the countless myriads of minute beings which lived and died within the bosom of that ancient lake.

In the limestones, associated with land and fresh-water shells, and remains of terrestrial plants, are bones of species of palæotherium, anoplotherium, lagomys, marten, dog, rat, tortoise, crocodile, serpent, and birds; the lava currents that have flowed over the strata have produced but little change in the organic remains. This series comprises beds of gypseous and laminated marls, with intercalations of siliceous limestone, containing impressions of lacustrine and river shells. In some localities, the fresh-water limestone has an intermixture of volcanic matter, and presents the characters of a sediment slowly and tranquilly deposited in a lake, into which ashes, and fragments of rocks and scoriæ, were projected by a neighbouring volcano; while some beds appear to have been formed by a violent intrusion of volcanic products.

3d. Immense beds of basalt, scoriæ, &c., spread over the tabular masses of fresh-water limestone, and often capping the summits of the lower hills. (Pl. II. fig. III.)

4th. Sand and diluvial gravel, containing bones of the mastodon, elephant, hippopotamus, rhinoceros, tapir, horse, boar, hyena, bear, dog, beaver, hare, &c.: with these are associated lignite, and other vegetable remains. Some of the beds of limestone abound in seed-vessels of charæ; and the laminated clays contain fishes, with leaves and stems of reeds and other plants.

There are several incrusting springs in Auvergne, largely impregnated with carbonic acid, which have deposited immense quantities of calcareous tufa. These issue from fissures in the granite and gneiss rocks that form the base of the whole territory, and are spread over the volcanic foci whence these mineral waters, in all probability, originate; numerous thermal springs also occur throughout the district.

51. SUCCESSIVE EPOCHS OF MAMMALIA.—The fossil remains of mammalia found in the sedimentary deposits of the volcanic region of Auvergne are very numerous, and comprise many of the most ancient species of the Paris basin, as well as those of existing ones. They are separated by Mr. Lyell,* and other eminent observers, into three groups;—

I. Mammalian remains from the fresh-water strata overlying the granite; these comprise bones of Palæotheria, Anoplotheria, and other Cuvierian pachyderms, associated with extinct species of Rhinoceros, Horse, Deer, &c.; this is the most ancient group.

II. Bones of Mastodon, Hippopotamus, Elephant, Horse, Tapir, Elk, Antelope, and many other terrestrial quadrupeds, all supposed to be extinct forms; associated with existing species of fresh-water shells. These are from the lacustrine deposits, which are separated from the above by ancient lava currents (*basalt*).

III. Fossil bones from the beds of sandy marl, and alluvial debris. These are referable to small Rodents (*Lagomys*), and nearly fifty species of other existing mammalia; as Mouse, Squirrel, Hare, Marten, Dog, Cat, &c.; Hog, Ox, Deer, and Horse; Frogs, Lizards, Snakes, and Birds; of the latter, even the eggs are occasionally found.

52. SUMMARY OF THE GEOLOGICAL PHENOMENA OF AUVERGNE.—In the calcareous and siliceous limestones of Auvergne, and their associated laminated marls, gypsum, lignite, and conglomerate, we have a general analogy with the older fresh-water tertiary formations of Paris; the shells and plants being similar, and the quadrupeds of the same genera. And if we suppose the

* See Proceedings of the Geol. Soc. 1845, p. 75.

Paris basin to have been elevated above the water during the active state of neighbouring volcanoes, and that successive streams of lava flowed over its sedimentary deposits, we should have a series of phenomena resembling those of Auvergne ; with the exception, that the presence of marine remains would denote that the basin had been filled with salt water, and communicated with the sea. The facts submitted to our notice appear to establish the following sequence of physical events.

1st. The elevation, after the deposition of the secondary limestones, of the whole area of the primary rocks which form the foundation of central France.

2dly. A period of tranquillity, during which fresh-water lakes occupied the irregular hollows of the district; the neighbouring country being inhabited by palæotheria, anoplotheria, and other extinct mammalia, whose bones, together with the relics of the then existing vegetation, and the shells of mollusca, became enveloped in the tranquil depositions that were going on in the lacustrine basins.

3dly. Another elevation of the district took place, a new system of lakes was established, and the country was again clothed with forests, and was inhabited by deer, oxen, rhinoceroses, and hyenas, măny of whose skeletons became imbedded in the sediments of the waters.

4thly. The volcanoes became active; explosions took place through hundreds of vents; trachyte and basalt were ejected, and in some places pierced the fresh-water deposits, while in others they overspread them with sheets of lava. Vegetation still flourished, and the remains of plants were entombed in the volcanic products.

5thly. Another period of tranquillity—the rivers and other water-courses, dammed up or deranged by the lava currents, formed new channels, and accumulated beds of gravel, sand, and clay. Deer, horses, oxen, &c., with hyenas and other carnivora, inhabited the district; having for contemporaries terrestrial mammalia of species which exist in Auvergne at the present time. Volcanic eruptions succeeded, and continued till a comparatively recent period.

Lastly. Streams and rivers of later date, and which still effect the drainage of the country, began to wear away channels through the beds of lava and limestone to the primary rocks beneath, and intersect the country with valleys and ravines, spreading over the ancient beds a thick covering of alluvial soil.*

53. Excavation of valleys by streams and rivers.—There is no district which exhibits in more striking characters the erosive power of running water, than Auvergne. In many places the basalt is columnar, like that of Staffa, and the Giants' Causeway ; and one range, on the banks of the Ardêche, forms a majestic colonnade 150 feet in height, extending a mile and a half along the valley which has been channelled out by the river that flows at its base.

Mr. Scrope's description of this process is highly graphic. "The bed of the Ardêche is strewed with basaltic boulders, pebbles, and sand, originating from the destruction of the columnar ranges. In some of the volcanic cones the beds of basalt may be traced issuing from the crater and following the inequalities of the valley, just as a stream of lava would flow down the same course at the present time. Yet these ancient currents have subsequently been corroded by rivers which have worn through a mass of rock 150 feet in height, and formed a channel even in the gneiss rocks beneath, since the lava first flowed into the valley. In another spot, a bed of basalt, 160 feet high, has been cut through by a mountain stream, and very beautiful columnar masses are exposed. The vast excavations effected by the erosive power of water along the valleys which feed the Ardêche, since their invasion by lava currents, prove that even the most recent of these volcanic eruptions belong to an era incalculably remote."

54. Extinct volcanoes of the Rhine.—I have dwelt

* This account of the volcanic phenomena of Auvergne, is an abstract of the interesting Essays of Messrs. Bakewell, Scrope, Lyell, Murchison, Dr. Daubeny, Dr. Hibbert, MM. Croiset, Jobert, Robert, and Bertrand-Roux. Mr. Scrope's work cannot be perused, even by the general reader, without deep interest.

so long on the Phlegræan fields of Auvergne, that but a brief space can be afforded to another group of tertiary volcanoes. Every one who has ascended the Rhine, will remember where

> "The castled crag of Drachenfels,
> Frowns o'er the wide and winding Rhine,"

forming one of the Siebengebirge, or Seven Mountains, whose majestic and graceful forms suddenly burst on the

LIGN. 49.—THE DRACHENFELS.

sight, rising from the level plains on the right bank of the river, to an altitude of nearly 1,500 feet. These picturesque objects belong to a group of extinct volcanoes; while, on the opposite side of the river, the Eifel, with its crater covered with scoriæ and cinders, and lava currents still distinctly visible, attest the wide area over which those ancient fires once extended. Unlike the district we have just noticed, the foundation rock of the country is an ancient sedimentary deposit, consisting of coarse red sandstone and slate, thrown into a highly inclined position. Through these beds the volcanic eruptions, consisting of trachyte, basalt, and other modifications of trap rocks and scoriæ, have forced their way. The basalt is black, and very compact, and breaks into sharp fragments; it is frequently columnar, and the separate hexagonal pillars are made use of for posts and pavements, in the adjacent towns. Such, says Mr. Horner,* is the profusion of basaltic pillars, that the walls of the town of Linz are wholly built of these materials, placed on their sides, with the ends projecting outwards. The streets are paved with the smaller columns set on end, thus forming a miniature representation of the Giants' Causeway; and the same volcanic product forms a large proportion of the walls of Bonn and Cologne. The secondary strata are covered by a series of tertiary deposits, consisting of sand, sandstone, clay, and *lignite;* constituting what is termed a *brown coal formation.* Upon these deposits is an extensive layer of gravel, which is covered by a deep bed of loosely coherent sandy loam, or mud, provincially termed *Loess.* This fine earthy detritus, which contains recent species of terrestrial and fresh-water shells, forms the subsoil of the vast plains in which Bonn and Coblentz are situated, and extends as far as the falls of Schaffhausen.

55. Brown coal formation.—As the usual condition in which bituminized vegetable matter occurs in the tertiary formations, is well exemplified in the brown coal, or *lignite,* of the Rhine, it will be instructive to examine the characters of this deposit somewhat in detail; for we shall thereby obtain data which will prepare us for the investigation of the ancient carboniferous system. This formation, which is spread over a great extent of country on both sides of the river, consists of clay, sand, sandstone, conglomerates, clay and ironstone, with lignite, or bituminized wood, of

* On the Geology of the Environs of Bonn, by Leonard Horner, Esq. F.R.S. Geological Transactions, vol. iv. 1836.

various qualities, disposed in distinct beds, and intermixed with argillaceous matter. The breadth of the ridge of low hills, formed by this assemblage of strata on the left bank of the Rhine, is from three to five miles, its elevation varying from 50 to 200 feet.

The lignite occurs in the following states :—1. A black earthy and pulverulent substance. 2. Concretionary masses, with leaves and fragments of wood. 3. Wood in various degrees of bituminization, and of shades of colour from a light-brown to jet-black. 4. Very finely laminated masses of bituminous matter and clay, of a dark chocolate colour, and separating into elastic flakes, as thin as paper, whence its name *papierkohle;* this substance is so highly bituminous as to burn with a bright flame. The wood is generally in small fragments, but stems of large trees, somewhat compressed, occasionally occur ; in some instances the trees are imbedded in an upright position, having the roots attached, and the stems passing through several beds of lignite. In many examples the wood is so little changed, that, like the timber of our peat-bogs, it is employed in building ; in others it is highly pyritous, that is, impregnated with sulphuret of iron, like the fossil vegetables of the Isle of Sheppey.

Mr. Horner is of opinion that there were extensive fresh-water lakes, in the sediments of which trees and plants, drifted by land-floods, were engulfed ; and that volcanic eruptions were simultaneously going on, in the same manner as in the modern submarine volcanoes. There is a great fault, or dislocation, in this brown coal formation, which he suggests may be attributed to a powerful and sudden volcanic explosion, that probably occasioned the elevation of the Siebengebirge, and raised up that portion of the coal-beds which reposes on the flanks of those peaks. The gravel covering the lignite, must have been strewn over the plain previously to this elevation, for it is found on both sides of the river at a great height, and not in the intermediate plain. These inductions are so evident as to require no comment.

The ancient alluvial deposit called the *Loess*, is a fine loam, containing fresh-water and land shells of many existing species ; a few bones of the horse and mammoth, are the only mammalian remains that have been discovered.* From the extensive distribution of this bed, and its occurrence at various elevations—in some instances on the flanks of mountains 1,200 feet above the level of the sea, at others spread out over the gravel of the vast plain of the Rhine—it is inferred, that although the *loess* has been deposited since the existing system of the hills and valleys of the country, yet great changes must have subsequently taken place in the physical geography of the district ; and Mr. Lyell states that there is reason to conclude, that since the deposition of this fluviatile loam, all the land between Switzerland and Holland has suffered a subsidence, and a subsequent elevation, to the amount of many hundred feet.

56. OTHER TERTIARY STRATA OF EUROPE, NORTH AMERICA, &c.—It has already been mentioned, that strata referable to the period comprehended between the uppermost secondary formations and the human epoch, occur throughout Europe ; presenting in some instances well-defined groups, with marked boundaries, and in others, vast areas, over which the deposits are irregularly spread. The geographical relations of the tertiary strata to the existing lands and seas, is an interesting subject of inquiry, but on which my limits forbid me to enter.† I may, however, observe, that Europe must have possessed many of its most striking physical characters at the commencement of the eocene period ; and that its present configuration has been produced by the conjoint effect of successive mutations in

* Principles of Geology, vol. iv. p. 33.

† Mr. Lyell's Principles of Geology should be consulted.

the relative level of land and water, during the deposition of the marine and fresh-water strata, reviewed in this discourse.

In North America the researches of Dr. Morton, Professor Vanuxem, Mr. Lyell, and other observers, have shown that in the territories of the United States eocene and miocene deposits extend over a great part of Maryland, along the coast of New York and New England, and occur in New Jersey, Delaware, Long Island, &c. The tertiary beds of Maryland consist of limestone, clay, sand, and gravel, and abound in the usual eocene shells ; some of which are identical with European tertiary species of *turritella*, *venericardia*, *fusus*, *ancilla*, &c. The remains of a large cetaceous animal, (named *Zeuglodon* from its deeply cleft teeth) are found in great numbers in the American eocene deposits.*

Infusorial marls of Virginia. The towns of Richmond and Petersburg in Virginia, are built on strata of siliceous marls, which extend over considerable tracts of country, and have an aggregate thickness of more than twenty feet. These marls, whose organic composition was first detected by Professor W. Rogers, are of the older tertiary (miocene or eocene) formations. The investigations of Dr. Bailey have shown, that these earths are almost wholly made up of the siliceous cases, or shields, of infusorial animalcules, termed *Navicula*, *Gaillonella*, *Actinocyclus*, *Coscinodiscus*, &c : the latter especially predominate, two or three species forming a large proportion of this aggregation of minute organisms. The *Coscinodisci* (or sieve-like discs) are elegant saucer-shaped shells, elaborately ornamented with hexagonal spots disposed in curves, and resembling the engine-turned sculpturing on a watch ; they vary in size from 1-100th to 1-1000th of an inch in diameter. If but a few grains of the Richmond earth are prepared for the microscope, all the varieties above specified are generally

* See Medals of Creation, vol. ii. p. 826.

displayed, so largely is this marl composed of the skeletons or shields of animalcules ; in fact, very few inorganic particles enter into its composition.*

57. ALTERED TERTIARY STRATA OF THE ANDES.—But striking as are the proofs already adduced of elevations and subsidences, and other effects of volcanic agency during the tertiary period, they sink into comparative insignificance, when contrasted with the enormous changes which have taken place in the great mountain chains of South America, during the same geological epoch. From the observations of Mr. Charles Darwin, we learn that an extensive tertiary system, analogous to that of Europe, skirts both flanks of the primary rocks which form the southern chain of the Andes ; the latter having suffered a certain degree of elevation before the deposition of the former. These strata, which are of great thickness and extent, are separable into two groups ; the lowermost beds, like those of Auvergne, repeatedly alternate with lavas, and thus denote the commencement of the eruptions of the ancient craters. Over these are accumulations of porphyritic pebbles, covered, at elevations of many hundred feet, by beds of shells of recent species ; and the sides of the mountains appear like a succession of sea-beaches, which have been slowly and tranquilly lifted up. The altered character of the tertiary deposits within the influence of the igneous products,—the conversion of beds of loose pebbles into solid, compact rocks,—and the occurrence of metalliferous veins in strata of comparatively modern origin,—are facts so powerfully exemplifying the geological principles enunciated in the former lectures, that though this discourse has extended to a great length, I cannot omit Mr. Darwin's graphic description of these phenomena, as originally communicated in a letter to Professor Henslow, of Cambridge, dated Valparaiso, March 1835.

* See the Article "*Fossil Animalcules,*" in Medals of Creation, vol. i. pp. 224—228.

"You will have heard of the dreadful earthquake of the 20th February. I wish some of the geologists, who think the earthquakes of these times are trifling, could see how the solid rocks are shivered. In the town there is not one house habitable; the ruins remind me of the drawings of the desolated eastern cities. We were at Valdivia at the time, and felt the shock very severely. The sensation was like that of skating over very thin ice, that is, distinct undulations were perceptible. The whole scene of Conception and Talesana is one of the most interesting spectacles we have beheld since we left England. I was much pleased at Chiloe by finding a *thick bed of recent oyster-shells capping the tertiary plain*, out of which grew large forest trees. I can prove that both sides of the Andes have risen in this recent period to a considerable height. Here the shells were 350 feet above the sea. On the bare sides of the Cordilleras, complicated dykes and wedges of variously coloured rocks are seen traversing, in every possible form and shape, the same formation, and thus proving by their intersections a succession of violences. The stratification in all the mountains is beautifully distinct, and, owing to a variety of colouring, can be seen at great distances. Porphyritic conglomerates, resting on granite, form the principal masses. I cannot imagine any part of the world presenting a more extraordinary scene of the breaking up of the crust of the globe, than these central peaks of the Andes. The strata in the highest pinnacles are almost universally inclined at an angle from 70° to 80°. I cannot tell you how much I enjoyed some of the views; it is alone worth coming from England to feel at once such intense delight. At an elevation of from ten to twelve thousand feet there is a transparency in the air, and a confusion of distances, and a stillness, which give the sensation of being in another world. The most important and most developed formation in Chili is the porphyritic concrete. From a great number of sections, I find it to be a true coarse conglomerate or breccia, which passes by every step in slow gradation to a fine clay-stone porphyry; *the pebbles and cement becoming porphyritic, till at last all is blended in one compact rock.* The porphyries are excessively abundant in this chain, and at least four-fifths of them, I am sure, *have been thus produced from sedimentary beds in situ.* The Uspellata range is geologically, although only six or seven thousand feet high, a continuation of the grand eastern chain. It has its nucleus of granite, consisting of beds of various crystalline rocks, (which I have no doubt are subaqueous lavas,) alternating with sandstone, conglomerates, and white aluminous beds, like decomposed felspar, with many other curious varieties of sedimentary deposits. In an escarpment of compact greenish sandstone, *I found a small wood of petrified trees in a vertical position;* or rather, the strata were inclined about 20° or 30° to one point of the trees, and 70° to the other; that is, before the tilt, they were truly vertical. The sandstone consists of many horizontal layers. Eleven of the trees are perfectly silicified, and resemble the dicotyledonous wood which I found at Chiloe and Conception; the others, from thirty to forty in number, I only know to be trees from the analogy of form and position; they consist of snow-white columns of coarsely crystallized carbonate of lime. The largest trunk is seven feet in circumference. They are all close together, within one hundred yards, and about the same level; no where else could I find any. It cannot be doubted that the layers of fine sandstone have quietly been deposited between a clump of trees, which were fixed by their roots. *The sandstone rests on lava; is covered by a great bed, apparently about one thousand feet thick, of black augite lava; and over this there are at least five grand alternations of such rocks, and aqueous sedimentary deposits, amounting in thickness to several thousand feet.* According to my view of these phenomena, the granite, which forms peaks of a height probably of 14,000 feet, has been fluid in the tertiary epoch; strata of that period have been altered by its heat and are traversed by dykes from the mass, and are now inclined at high angles, and form regular or complicated anticlinal lines. *To complete the climax, these same sedimentary strata and lavas are traversed by very numerous true metallic veins of iron, copper, arsenic, silver, and gold, and these can be traced o the underlying granite. A gold mine has been worked close to the clump of silicified trees!*"

58. Tertiary saliferous deposit.—Not only coal, but even extensive beds of rock salt occur in the tertiary system. The celebrated salt mines of Galicia, of which M. Boué* has given an interesting description, belong to this epoch. The deposit is nearly 3000 yards long, 1066 broad, and 280 yards deep. The upper part of the mine consists of green salt, with nodules of gypsum in marl. The salt contains in some places lignite, bituminous wood, and shells. In the lower division are beds of arenaceous marls, with lignite, impressions of plants, and veins of salt; coarse sandstone, with vegetable remains; aluminous and

* Journal de Géologie.

gypseous shale, and indurated calcareous marl, with sulphur, salt, and gypsum.

59. Retrospect.—So numerous and varied have been the phenomena presented to our notice, that a comprehensive retrospect is necessary, in order to obtain a correct idea of the highly interesting deductions resulting from this general survey of the tertiary formations.

In the newer tertiary, or pliocene, including the mammalian epoch of the last lecture, the fossil remains in the alluvial deposits afford incontestible proof that the mammoth, mastodon, hippopotamus, dinotherium, elk, and other colossal animals of extinct species and genera, together with birds, reptiles, and carnivora, inhabited such districts of our continents as were then above the waters ; while the older tertiary, or eocene, inclose the bones of land animals, principally pachyderms, approximating to certain races that now exist in the torrid zone, but which belong to extinct genera. The seas and lakes of that remote epoch occupied areas, the greater part of which is now dry land ; and rocks and mountains, hills and valleys, streams and rivers, diversified the surface of countries which have since been either destroyed, or entirely changed; and whose past existence is only revealed by the deposits that were accumulated in the lakes and deltas, by streams and rivers. The ocean abounded in mollusca, crustacea, and fishes, of which a large proportion is referable to extinct species. Crocodiles, turtles, birds, and insects, were contemporary with the palæotheria, and anoplotheria; and animal organization, however varied in certain types, presented the same general characters as in modern times; the extinction of species and genera being then, as now, in constant activity. The vegetable world also contained the same great divisions ; there were forests of oak, elm, and beech ; of firs, pines, and other coniferous trees ; palms, tree-ferns, and the principal groups of our modern floras ; while the water, both salt and fresh, teemed with the few and simple forms of vegetable structure peculiar to that element.

The state of the inorganic world is not less manifest: the abrasion of the land by streams and rivers,—the destruction of the sea-shores by the waves, and the formation of beach and shingle,—the desolation inflicted by volcanic eruptions,—all these operations were then, as now, in activity. The bed of an ancient sea, containing myriads of the remains of fishes, crustacea, and shells, now forms the site of the capital of Great Britain; and accumulations of tropical fruits and plants, with remains of crocodiles, serpents, turtles, and birds, drifted by ancient currents from other climes, constitute islands in the estuary of the Thames; while the sediments of inland seas, lakes, and gulfs, teeming with the skeletons of beings which are blotted out from the face of the earth, compose the country around the metropolis of France.

Notwithstanding that the changes in the relative level of the land and sea during this epoch were numerous and extensive, one region still preserves traces of its original physical geography; and though the earthquake has rent its mountains to their very centre—though hundreds of volcanoes have again and again spread desolation over the land—and inundations and mountain torrents have excavated valleys, and chequered the plains with ravines and water-courses—yet the grand primeval features of that country remain; and we can trace the boundaries of its ancient lakes, and the successive changes which its surface has undergone, from the first outbreak of its volcanoes, to the commencement of the present state of repose. The lowermost lacustrine deposits in Auvergne, which are spread over the foundation rocks of gneiss and granite unmixed with igneous productions, mark the period antecedent to the volcanic era; while the intrusions of lava and scoriæ in the superincumbent strata, denote the first eruptions of Mont Dome. The succeeding period of tranquillity is recorded in characters alike intelligible. The slow deposition of calcareous mud—the incrustation of successive generations of aquatic insects, crustacea, mollusca, and infusoria—the imbedding of the bones of mammalia, birds, and reptiles—the accumulation of lignite and other vegetable matter—are data from which we may restore the ancient country of Central France.

It was a region encircled by a chain of granite mountains, watered by numerous streams and rivulets, and possessing lakes of vast extent. Its soil was covered with luxuriant vegetation, and peopled by palæotheria, anoplotheria, and other terrestrial mammalia ; the crocodile and turtle found shelter in its marshes and rivers ; aquatic birds frequented its fens, and sported over the surface of its lakes ; while myriads of insects swarmed in the air, and passed through their wonderful metamorphoses in the waters. In a neighbouring region,* herds of ruminants and other herbivora, of species and genera now no more, with birds and reptiles, were the undisturbed occupants of a country abounding in palms and tree-ferns, and having rivers and lakes, with gulfs which teemed with the inhabitants of the sea ; but to this district the fiery torrents of the volcano did not extend. But to return to Auvergne ; a change came over the scene—violent eruptions burst forth from craters long silent—the whole country was laid desolate—its living population was swept away—all was one vast waste, and sterility succeeded to the former luxuriance of life and beauty. Ages rolled by—the mists of the mountains and the rains produced new springs, torrents, and rivers—a fertile soil gradually accumulated over the cooled lava currents and the beds of scoriæ, to which the sediments of the ancient lakes, borne down by the streams, largely contributed. Another vegetation sprang

* The Paris basin.

up—the mammoth and mastodon, with enormous deer and oxen, now quietly browsed in the verdant plains—other changes succeeded—those colossal forms of life in their turn passed away, and at length the earlier races of mankind took possession of a country, which had once more become a scene of fertility and repose.

To those who have favoured me with their attention through this discourse, it cannot be necessary to aver, that the successive changes in organic and inorganic nature thus rapidly portrayed, are supported by proofs so incontrovertible, and traced in characters so intelligible, as to constitute a body of evidence with which no human testimony can compete. It is true that the time required for this succession of events must have extended over an immense period ; but time and change are great only in relation to the beings which note them, and every step we take in geology shows the folly and presumption of attempting to measure the operations of nature by our own brief span. "There are no minds," says Mr. Scrope, "that would for one moment doubt that the God of Nature has existed *from all eternity ;* but there are many who would reject as preposterous, the idea of tracing back the history of *His works* a million of years. Yet what is a million, or a million of millions of years, when compared to eternity ?"*

Germany presents us with an interesting series of analogous changes, effected in a later era. The outburst of the now extinct volcanoes of the Rhine, the accumulation of fluviatile silt over the plains, and the subsequent elevation of the whole country, show that these physical mutations were not confined to a single region or period.

In the Andes, the enormous disruptions and elevations of the most ancient as well as modern deposits, teach us, that through a long lapse of ages, the volcanic fires of South America have acted with intense energy ; and yet more,

* Geology of Central France.

that the melting and transmutation of loose materials into compact rocks, the conversion of incoherent strata into solid stone, and even the sublimation of gold and other metals into fissures and veins, are phenomena which have taken place since our seas were peopled by mollusca of existing species. The importance of these extraordinary and interesting facts will be rendered more obvious in a subsequent lecture.

60. Concluding remarks.—In conclusion, it will be useful to inquire, even though some repetition may be incurred, what are the legitimate inferences from the facts that have been placed before us, as to the condition of our globe and its inhabitants during the tertiary epoch? Was there, as some have supposed, an essential difference in the constitution of the earth?—was its surface more covered with lakes and marshes than now?—and did animal life more abound in those types, which are suitable to a lacustrine condition?—or have such conclusions been drawn from a partial view of the phenomena, and do the facts only warrant the inference, that certain regions which are now dry land, were in ancient times submerged beneath the sea, or covered by vast lakes; and that there may have existed contemporaneously, as great an extent of dry land as at present, in areas now buried beneath the ocean?—In the fossilized remains of the population of the tertiary lands and waters, we find all the grand types of the existing faunas—terrestrial, lacustrine, and marine mammalia—herbivora, carnivora, birds of every order, and of numerous species and genera—reptiles, fishes, crustacea, insects, zoophytes, and even those living atoms, the infusoria—in short, all the leading divisions, and subdivisions of the animal creation. In the vegetable world the same general analogy is maintained; and as all these varied forms of being required corresponding physical conditions, we have at once conclusive evidence that the general constitution of the earth,

and the correlation between the organic and inorganic kingdoms of nature, during the tertiary epoch, were essentially the same as at present. Dry land and water, continents and islands, existed then, as now,—their geographical distribution may have varied,—the temperature in certain latitudes may have been much higher,—fertile countries may have occupied areas now covered by water, and marshes and fens have prevailed in regions now arid and waste ; but the same agents of destruction and of renovation were then in as constant activity as at present. It is true that immense numbers of large mammalia lie buried in regions where such creatures could not now find subsistence, and in latitudes where the climate is at this time unsuitable to such forms of organization. But some of these apparent anomalies may be explained by the fact, that the alluvial beds in which these remains occur cannot have been the sites of the dry land on which these extinct beings existed; they are the sediments of ancient lakes—the deltas of former rivers—the estuaries of seas—they are formed of the detritus of the land transported from a distance, and spread over areas then submerged beneath the waters. If the Gulf-stream annually strews the shores of the Hebrides with the fruits of torrid climes, the currents of the ancient seas must have produced analogous results ; and in our attempts to interpret past changes, it must not be forgotten that they have most probably been produced by causes similar to those which are still in action. I do not question the assumption, that some of the countries containing these fossil remains, may have enjoyed a milder climate during the tertiary ages than at present ; or that in still more ancient periods there may not have prevailed a much higher temperature ; but it appears to me, that the variation of climate which a change in the relative distribution of the land and water would occasion, as suggested by Mr. Lyell,*—and a difference in the radiation of heat

* Principles of Geology, vol. i. chap. vii.

from internal sources, as explained by Sir J. Herschel and Mr. Babbage,—may account for all the phenomena of this nature, which our examination of the tertiary formations has revealed.

The occurrence of groups of animals of the same families, in certain districts, is in strict conformity with the distribution of living species in regions not under the control of man. Thus when ancient France presented a system of lakes, animals fitted for such physical conditions found there the means of subsistence—when the vast plains and forests of America were adapted for colossal mammalia, there the mastodon and the mammoth obtained food and shelter—and when the former continent of Europe swarmed with herbivora, the carnivorous tribes, as the lion, the tiger, and the hyena, obtained the support which their habits and economy required.

One striking feature in the events that have passed in review before us, is the immense scale on which the extinction of species and genera seems to have been effected: but it must be remembered, that our observations have extended over periods of vast duration, and that we have been contemplating the aggregate effects of a law, which even in modern times has produced, and is still producing, great and important modifications in the system of animated nature. In our attempts to penetrate the mystery which veils the early scenes of the earth's physical history, by a reference to the effects of the laws which now govern the organic and inorganic kingdoms of nature, the caution of the illustrious philosopher Playfair, should be ever present to our minds:—"If existing causes appear to be inadequate to the effects produced, it may be only that, in respect to man, their movements are too slow to be perceived. The utmost portion of the progress to which human experience can extend, is evanescent in comparison of the whole, and must be regarded as the momentary increment of a vast progression, circumscribed by no other limits than the duration of the world. Time performs the office of integrating the infinite small parts of which the progression is made up—it collects them into one scene, and produces from them an amount far greater than any that can be assigned from human observation." *

Thus the tertiary epoch displays to us a state of the globe replete with life: the physical constitution of the earth's surface, and the condition of the land and sea, being adapted to the habits and economy of beings of the same types of organization as those which exist at the present time. In the most ancient periods certain forms of life prevailed, and gradually became extinct, and were succeeded by others which in their turn also passed away; and in tracing the varying types of vitality from the earliest ages, we perceive a gradual approach to the present condition of organic nature, in the contemporaneous existence of extinct forms with those which now exist; the grand line of separation between the present and the past being the creation of the human race. From that era, in proportion as Man has extended his dominion over the earth, many races of animals have been either exterminated, or modified, by his caprices or necessities; and it cannot be doubted, that in the lapse of a few thousand years, vast changes will be effected by human agency alone, in the geographical distribution and relative numerical proportion of many of the existing genera and species of animals.

* Illustrations of the Huttonian Theory.

LECTURE IV.

Part I.

1. Introductory. 2. Formations of the Secondary Epoch. 3. Cretaceous Formation. 4. Chalk Downs. 5. Flint nodules and veins. 6. Organic remains in flint. 7. Animalcules in flint. 8. Xanthidia. 9. Middle and Lower groups of the cretaceous strata. 10. Folkstone Cliffs. 11. Cretaceous strata of Mæstricht. 12. The Mosasaurus. 13. Cretaceous deposits of other countries. 14. Organic remains of the Chalk Formation. 15. Fossil vegetables. 16. Zoophytes of the Chalk. 17. Animalculites of the Chalk. 18. Chalk Rotaliæ. 19. Chalk detritus at Charing. 20. Spirolinites. 21. Crinoidea of the Chalk. 22. Star-fish. 23. Echinites. 24. Shells of the Chalk. 25. Cephalopoda. 26. The Nautilus. 27. Ammonites 28. Turrilites and Hamites. 29. The Belemnite. 30. Crustaceans of the Chalk. 31. Fishes of the Chalk. 32. Scales of Fishes. 33. Teeth of Sharks. 34. Hypsodon and other fishes. 35. Fossil Salmon. 36. The Macropoma. 37. Beryx, and other fishes of the Chalk. 38. Reptiles of the Chalk. 39. Fossil Turtles. 40. Summary.—Tabular arrangement of Sussex Chalk fishes.

1. Introductory.—The knowledge we have acquired from our investigation of the phenomena described in the previous lectures, will materially facilitate our geological progress, by enabling us to comprehend the former effects of those physical agencies, by which the surface of the earth has been perpetually renovated, and maintained in a suitable condition for the existence of successive races of animated beings.

The elevation of the beds of seas and rivers, and their conversion into fertile countries—the submergence of islands and continents beneath the waters of the ocean—the rapid formation of conglomerates from shells and corals on the sea-shore—the accumulation of beach and gravel, and the inhumation of animals and vegetables--the slow deposition of sediments by lakes and rivers—the imbedding of innumerable generations of insects, and the formation of limestone from their almost invisible skeletons—the construction of solid stone out of fragments of bones and rocks, shivered by earthquakes—the engulfing in estuaries and inland seas, of land animals, birds, and reptiles—the conversion of organic and inorganic substances into rock, from the infiltration of flint and lime by thermal waters—the transmutation of submerged forests into coal and lignite—the destructive and conservative effects of volcanic eruptions—the consolidation of sand, gravel, and clay, into indurated masses by heat—and the production of metalliferous veins of gold and silver—all these phenomena have passed in review before us, although our inquiries have extended through periods which, however vast and remote in relation to the records of our race, are but brief and modern in the physical history of our planet.

The geological events previously described, though forming a connected series, may be divided into periods, each of which is marked by certain zoological characters; namely, 1st. The *Modern*, or *Human Epoch;* 2d. The *Elephantine*, characterized by the preponderance of large pachydermata; 3d. The *Palæotherian*, in which animals allied to the tapirs prevailed, and Europe presented a system of gulfs and lakes.

2. FORMATIONS OF THE SECONDARY EPOCH.—We proceed to the consideration of an antecedent epoch,—that which comprehends the Secondary Formations. Hitherto our attention has been principally directed to deposits confined within comparatively limited areas, as the basins of lakes, gulfs, estuaries, and inland seas; and the superficial accumulations of drifted materials, produced by the action of torrents, rivers, icebergs, glaciers, inundations, &c. We have now arrived on the shores of that ocean, of whose spoils the

existing islands and continents are principally composed; the fathomless depths of the ancient seas are spread before us, and the relics of innumerable myriads of beings which lived and died in their waters, and became entombed in their profound abysses, remain, like the mummies of ancient Egypt, the silent yet eloquent teachers of their own eventful history.

A reference to the Tabular Synopsis (p. 200), will show that the secondary formations constitute ten principal subdivisions; viz. the *Cretaceous*, *Wealden*, *Oolitic* and *Liassic*, *Triassic*, *Permian*, *Carboniferous*, *Devonian*, *Silurian*, and *Cumbrian* systems, each containing littoral, and oceanic deposits; sandstones having been formed amidst the agitated waters of the sea shores; clays in tranquil bays and gulfs; and limestones in deep water. I purpose, in the present discourse, to explain the geological characters of the first two of the series, namely, the CHALK and the WEALDEN.* The former is composed of rocks that have been accumulated in the depths of a sea of great extent; the latter, of the sediments of a vast delta; the one affording a striking illustration of the nature of *oceanic*, and the other of *fluviatile* deposits. As both the Chalk and the Wealden are fully developed in the south-east of England, the phenomena about to be described may be readily examined, and collections of the peculiar fossils of these formations obtained, with but little trouble.†

* The term Wealden is derived from the German *Wald*, signifying a Wood or Forest. The *Weald* of Sussex was formerly an impenetrable forest, called *Anderida* by the Romans, and *Andreadswald* by the Saxons.

† Since the earlier editions of this work, the Author's extensive collection of the Fossils of the south-east of England has been purchased by the Trustees of the British Museum. A brief compendium of its contents was published by the Sussex Royal Institution, under the title of "*Descriptive Catalogue of the Mantellian Museum at Brighton*," 8vo. Brighton, 1836: fifth edition.

3. The Cretaceous or Chalk formation.—The pure white limestone called *Chalk*, is known to every one; but in the nomenclature of geology, the term is applied to a group of deposits very dissimilar in lithological composition, but agreeing in the nature of the organic remains which they contain, and evidently referable to the same geological epoch. The series essentially consists of green and ferruginous sands, clays, marls, and grey and white limestones, abounding in mariné remains. With this explanation it will be convenient to employ the term in its extended sense. The Chalk Formation comprises the following principal subdivisions:—

1. *Upper chalk*, with flints		*Craie blanche* of the French Geologists.
2. *Lower chalk*, without flints . . .		
3. *Firestone*,	Chalk marl	*Craie tufeau.*
	Upper green sand, or Glauconite	*Glauconie crayeuse.*
4. *Galt*, or Folkstone marl		
5. *Greensand*, or Shanklin, or Lower-green-sand		*Glauconie sableuse.* *Terrain Néocomien.*

The *Chalk* is generally white, but in some countries is of a deep red, and in others of a yellow colour; nodules and veins of flint occur in the upper division, but seldom in the lower chalk of England. The *Marl* is an argillaceous limestone, which is very constantly found underlying the chalk; the lower beds contain a large intermixture of green sand, and form a coarse calcareous sandstone, called *Firestone*. The *Galt* is a stiff, dark blue clay, abounding in shells, which, as in most argillaceous beds, retain their pearly investment unimpaired in lustre. The *Greensand* is a triple alternation of sands and sandstone with clays; with beds of chert and fuller's earth in some localities.

On the Continent the cretaceous deposits are largely developed; and taken as a whole, the chalk formation may be described as extending over a great part of the south-east of

England, Northern France, Germany, Denmark, Sweden, European and Asiatic Russia, and of the United States of North America. Over this vast extent, the organic remains present certain general characters, sufficiently precise to determine the nature of the deposits. Whether imbedded in pure white limestone, coarse sandstone, blue clay, loose sand, or compact rock, the fossils consist, for the most part, of species of the same genera of shells, corals, sponges, echinites, belemnites, ammonites, and other marine animal exuviæ; fishes, reptiles, wood, and plants. The white chalk strata extend along a great part of the Hampshire, Sussex, and Kentish coasts; the precipitous headland of Beachy Head, and the cliffs at Dover are well known; these natural sections exhibit the manner in which the beds have been displaced, and thrown into various inclined positions.*

Along the southern coast of the Isle of Wight, the entire series comprised in the Cretaceous formation is exposed to view; and the characters and relations of the various deposits may be studied with facility, either on the south-eastern or south-western coasts of the "beautiful island." The white chalk strata, thrown into a nearly vertical position, and boldly displayed, on the east at *Culver Cliff*, and on the west at the *Needles*, traverse the island from east to west; being covered on the north by tertiary deposits. In Sandown Bay, the strata have an anticlinal position,† and on each side the axis of elevation, the several members of the Chalk, namely the greensand, galt, firestone, marl, and chalk, appear in their

* See The Fossils of the South Downs, or Illustrations of the Geology of Sussex, 1 vol. 4to. with 42 plates. Geology of the South-East of England, 1 vol. 8vo. Medals of Creation. Geology of the Isle of Wight.

† *Anticlinal:* a term applied to strata which incline or dip towards each other, or from a central axis, like the ridge-tiles on the roof of a house.

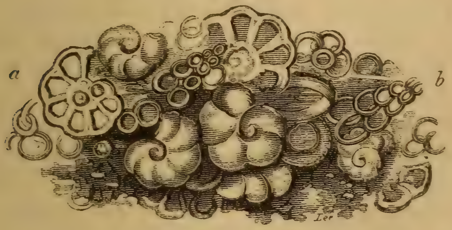
natural order of succession. A similar section is seen in Compton Bay; while along the Undercliff, fallen masses of the upper beds, intermingled with detritus, form the ruinous cliffs of that picturesque tract; and beyond, at Black-gang and Atherfield, the greensand series constitutes the line of coast; the Wealden forming the cliffs in Brixton and Brook bays; but the details of this interesting district are so fully given in my recent work,* that I need not enter at length upon the subject.

4. Chalk Downs.—The features of a chalk district are very peculiar, when the surface has not been broken up for tillage, or is not concealed by dense woods and forests. The rounded summits of the hills clothed with short verdant turf—the smooth undulated outlines of the Downs, unbroken save by the sepulchral mounds of the early inhabitants of the country—the coombes and furrows, ramifying and extending into the deep valleys which abruptly terminate at the base of the hills, and appear like dried up channels of rivulets and streams, though free from all traces of alluvial debris; thus bearing the impress of physical operations of which the agents that produced them have long since passed away—are phenomena that must be familiar to every one who has travelled over the downs of the south-east of England. These features are restricted to the hilly districts where the *white-chalk* forms the subsoil, and have resulted from the peculiar nature of the sedimentary detritus of which the strata comprised in the upper division of the cretaceous system are composed. For where the lower group of clays, marls, sands, and sandstones approaches the surface and forms the subsoil, the country is broken and diversified, and the landscape presents a striking contrast with the down scenery.

* Geological Excursions round the Isle of Wight and along the adjacent Coast of Dorsetshire, 1 vol. 8vo. with numerous illustrations, sections, map, &c. H. G. Bohn, London, 1847.

The upper division of the cretaceous system is composed of beds of a very peculiar white limestone, varying in thickness from a few inches to several feet. In the *Upper Chalk* there are numerous parallel rows of siliceous nodules, termed flints, disposed in irregular distances from each other; and in some places sheets or seams of flint are intercalated between the chalk strata, and extend over considerable areas. The chalk is also traversed by vertical and diagonal veins of flint. The only metallic substances are oxide of manganese, in the state of dendritical or arborescent markings; and oxides and sulphurets of iron. Iron-pyrites frequently constitutes the casts of shells, echini, &c.—the surface of the mineral retaining sharp imprints of the external characters of the original.

The white chalk is composed of lime and carbonic acid; and a microscopical analysis proves it to be a mere aggregation of shells and corals, so minute that upwards of a million are contained in a cubic inch of the rock; the



LIGN. 50.—CHALK-DUST; highly magnified, seen by reflected light.
a, a. Rotaliæ. *b.* Textilariæ.
(*From "Thoughts on a Pebble."*)

amorphous particles appear to be the detritus of similar structures, and not a chemical precipitate. The appearance of a few atoms of chalk-dust, under a highly magnifying power, is shown in this figure (*Lign.* 50). These organisms are the calcareous cases and shells of the animalcules termed *Foraminifera*,* which swarm in inconceivable numbers in our present seas, and are daily and hourly contributing to the amount of sediment now accumulating in the bed of the ocean.

5. Flint nodules and veins.—The *flints* (as the siliceous nodules are generally termed) occur in horizontal rows or layers, generally parallel with the lines of stratification of the chalk, but placed at unequal distances from each other. They are of all sizes, from that of a small nut to masses several feet in circumference. But besides these parallel beds, there are sheets of flint intercalated between the chalk strata, and covering areas, often many miles in extent. These continuous layers are termed tabular flint; they are seldom more than two or three inches in thickness, and veins and threads of silex frequently ramify from them into the fissures of the surrounding chalk. This tabular flint is generally solid throughout, but sometimes incloses a layer of chalky matter, full of the usual minute organisms of the chalk. Vertical and diagonal veins of flint filling up crevices and fissures in the rock, and traversing both the strata of limestone and any sheets of tabular flint that may be interposed, are of common occurrence; these prove that the lower beds were consolidated, and had subsequently been fissured, before the superimposed strata were deposited, and the streams of siliceous matter flowed over them.

The nodules and veins of flint that are so abundant in the upper chalk, have probably been produced by the agency of heated waters and vapours. The perfect fluidity of the siliceous matter before its consolidation, is proved not only by the sharp moulds and impressions of shells, &c. retained by the flints, but also by the presence of numerous organic bodies in the substance of the nodular masses, and the silicified condition of the sponges and other zoophytes

* Medals of Creation, vol. i. p. 228.

which swarm in some of the cretaceous strata. For though silex or the earth of flint is insoluble in boiling water, its solution, as we have previously stated (p. 93), readily takes place in vapour heated to a temperature above that of fused cast-iron (p. 100) ; and similar effects are being produced at the present moment by the thermal waters of active volcanoes (p. 98).

The temperature to which water may be raised, depends on the presence or absence of air ; for it has been proved by direct experiment that water deprived of air may be heated to 275° of Fahrenheit, under the ordinary pressure of the atmosphere, without exhibiting any symptoms of ebullition. The solvent power of water on rocks containing silex may, therefore, be fully adequate to produce all the phenomena presented by the siliceous nodules, veins, dikes, &c. of the chalk formation ; and our chalk flints may possibly have originated from the quartz of granitic and other plutonic rocks, dissolved in heated water, and erupted into the basin of the ancient chalk ocean.

6. Organic remains in flint.—In many instances the organic remains in chalk flints are simply incrusted by silex : such is the state of numerous sponges which are as it were invested by the flint, and have their pores and tubes filled by the same material ; the original tissue appearing as a brown earth. In other examples the sponge has been enveloped by a mass of liquid silex, and subsequently perished ; in this manner have been formed those hollow nodules, which on being broken present a cavity containing only a little white powder, or some fragments of silicified sponge : while in other instances the cavity is lined with quartz or chalcedony. It frequently happens that only part of the zoophyte is permeated by silex, while the other portion is in the state of a friable calcareous earth imbedded in the chalk.

Sponges and other organic bodies often form the nuclei of flint nodules, and the original substance of the fossil is generally silicified, and the most delicate internal structure preserved. In other instances the inclosed organisms have undergone no change, but appear as if immersed and preserved in a semi-transparent medium; such is the state in which foraminiferous shells, corals, &c. often occur. An exquisite example of this kind was discovered by the Marquess of Northampton, in a chalk flint from Brighton; in polished slices of this specimen, numerous branches of delicate corals (*Pustulopora*, *Retepora*, *Idmonea*, &c.*) and foraminifera, appear as perfect and unaltered as if imbedded in glass.

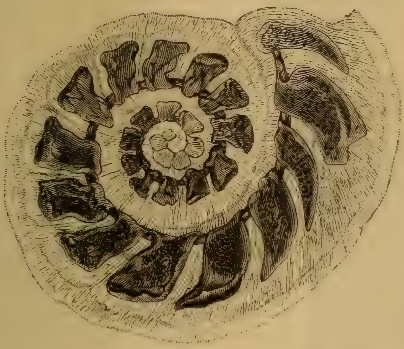
But there are innumerable flint nodules which exhibit no traces of spongeous structure; and veins, dikes, and sheets of tabular flint, that may be regarded as pure, and free from organic remains, excepting such as must inevitably have become entangled and imbedded in a stream of mineral matter flowing over a sea-bottom. Wood which has been perforated by lithodomi, and silicified, is not scarce; and confervæ and fuci are sometimes found floating, as it were, in the liquid silex. Bones of reptiles and fishes are often impacted in a mass of flint; but in only one instance have I observed that the silex has permeated the osseous structure.

7. Animalcules in flint.—For the most part, the minute shells of the chalk and flint are filled with amorphous mineral matter; but in many examples, as I have ascertained by direct experiment,† the soft parts or body of the animalcule remain in the shell; sometimes completely silicified, but in others in the state of *dried animal membrane*, like the ink-bag of the cuttle-fish in lias, the soft parts of

* Medals of Creation, vol. i. p. 284.

† See my observations "*On the Fossil Remains of the soft parts of Foraminifera*, discovered in the chalk and flint of the S. E. of England." Philosophical Transactions, 1846, part iv.

cephalopoda in clay, and the capsule of the eye and membranes of the stomach in certain fishes of the chalk.* In the flints such specimens are by no means rare, and from the semi-transparency of that mineral, are easily detected under the microscope. The annexed figure (*Lign.* 51)



LIGN. 51.—THE SHELL OF A ROTALIA, CONTAINING THE FOSSILIZED REMAINS OF THE BODY OF THE ANIMAL; IN FLINT *(highly magnified)*.†

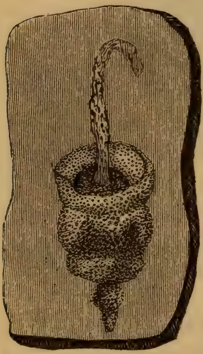
represents the body of a *Rotalia*, in its shell, imbedded in flint; the original is invisible to the naked eye, but under a good microscope its structure is beautifully defined; the

* I would refer the general reader, who is not conversant with the various conditions in which the remains of vegetables and animals occur in the mineral kingdom, according to the circumstances under which they were originally imbedded, and the chemical changes they may have subsequently undergone, to my remarks "*On the Nature of Fossils or Organic Remains*," Medals of Creation, vol. i. chap. iii. See also "*Instructions for the collecting of Fossils*," vol. ii. p. 885.

† Specimens of the Rotaliæ, Xanthidia, and other minute fossil organisms of the chalk and flint, may be obtained of *Mr. Topping*, the well-known microscopic artist, No. 1, York Place, Pentonville Hill, London. See Medals of Creation, vol. i. pp. 78, 244, for "*Instructions how to prepare Fossils for the Microscope.*"

folds of the membrane in the cells being as obvious as in a specimen obtained from the sea.

The shells of the Rotaliæ and Textilariæ in the chalk, also contain the desiccated soft parts of the animalcules unmineralized; and by dissolving the chalk and shells in weak hydrochloric acid, and immersing the residue in a transparent medium (*Canada balsam*), the tissues are as distinctly seen as in the recent state. I shall again refer to this subject when treating of the organic remains of the cretaceous system. In this place, however, I would call your attention to an exquisite example of the preservation of the soft parts of an animalcule in flint. The fossil here delineated (*Lign.* 52) was discovered by my friend the Rev. J. B. Reade,* a gentleman well known for his accurate microscopic investigations. It is evidently a coral, from the cell of which a polype protruded, when it became enveloped in the fluid silex: with the exception of the tentacula, which appear either to have perished, or to have collapsed so as not to be distinguishable, the form and structure of the original are admirably preserved.



LIGN. 52.
A CORAL-POLYPE, in flint, (*magnified 500 diameters*).

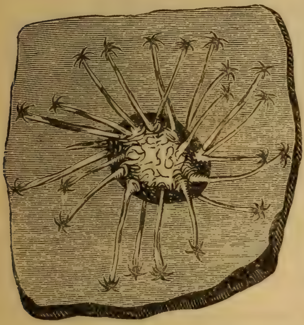
8. XANTHIDIA.—The minute microscopic spherical bodies, to which Ehrenberg has given the name of *Xanthidia*, from the supposition of their analogy to the spores of certain kinds of *Desmideæ*,† are so abundant in the flints, that I must briefly notice them in this place. These fossils occur both in the chalk and flint; and though generally

* Rector of Stone, Bucks.

† *Desmideæ:* a group of organisms of doubtful affinity; being considered by some naturalists as vegetable, by others as animal structures.

silicified, have been detected unmineralized in the chalk, and as flexible as the soft parts of the rotaliæ.*

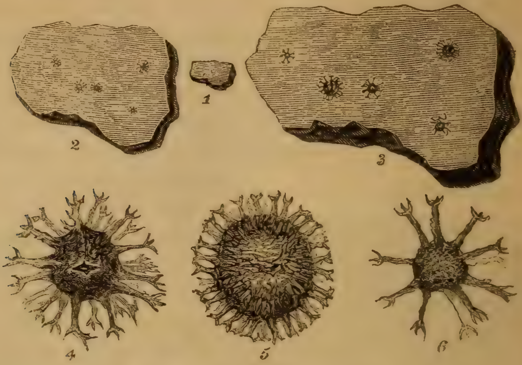
The fossil Xanthidia, (the true nature of which is, I think, still problematical,) are hollow globular or spherical bodies, beset with spines or tubular processes, which, in many species, are fimbriated at the extremities, and vary considerably in number and length. Some species (*Lign.* 53), have these appendages very long, and their extremities patulous and fimbriated. In a rare species (discovered by my son), the spines are short, equal, and relatively thick (*Lign.* 54, *fig.* 5); in others they are intermediate in length, proportions, and number (as in *Lign.* 54, *fig.* 4, 6). The manner in which these bodies occur in the flint, is shown in the example figured in *Lign.* 54; which is a thin chip containing five Xanthidia, that was broken off at random from a nodule. The specimen is represented of the natural size in *fig.* 1; slightly magnified as seen by transmitted light in *fig.* 2; and under a higher power in *fig.* 3; the fragment having been previously rendered as transparent as glass by immersion in Canada balsam.



Lign. 53.—Xanthidium palmatum. (*Drawn by Rev. J. B. Reade; magnified* 500 *diameters.*)

* The Xanthidia were first discovered in this state by Mr. Deane, of Clapham, an able microscopic observer, to whom I am indebted for my choicest specimens of the soft parts of Rotaliæ. See Philos. Trans. 1846, p. 466.

Figs. 4, 5, 6, represent the three best defined specimens highly magnified.*



LIGN. 54.—XANTHIDIA IN FLINT.

(*By Reginald Neville Mantell.*)

Fig. 1. A thin, transparent, chip of flint: natural size.
2. The same magnified, viewed by transmitted light.
3. More highly magnified.
4. *Xanthidium ramosum;* one of the animalculites seen in the previous figures, magnified 300 diameters.
5. *Xanthidium Reginaldi;* from the same group: a very rare species.
6. Another variety of Xanthidium ramosum.

9. MIDDLE AND LOWER GROUP OF THE CHALK FORMATION.—Beneath the Chalk with flints, is a series of strata of equal thickness, termed the *Lower Chalk*, in which no flints are met with in England, except in a few localities; in some places on the Continent, however, nodules

* The Xanthidia which occur in the English chalk flints, were first noticed and figured by the Rev. J. B. Reade, in the Annals of Nat. Hist. 1838; they have since been made the subject of an elegant memoir, published in the Transactions of the Microscopical Society of London, vol. i. p. 77, by H. Hopley White, Esq. of Clapham. A specimen from chalk, by Mr. Deane, is figured in Philos. Trans. 1846, Pl. XXI. fig. 1.

and veins of flint occur in the lowermost beds of white chalk. The inferior members of this formation, the *Firestone*, *Galt*, and *Greensand*, are constant in their characters and relations, in England, and over a great part of the Continent of Europe: the following is a concise view of these deposits, in connexion with the upper group.

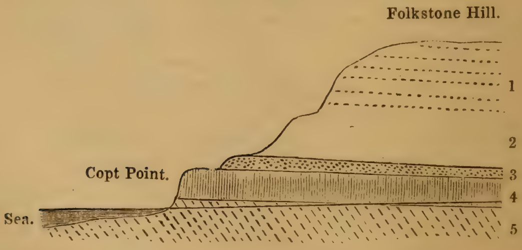
CHALK FORMATION.

Upper Chalk.	Strata of white limestone, with parallel layers of siliceous nodules, and veins and tabular masses of flint. Chalcedony; Calc-spar. Pyrites; quartz pebbles.	Marine shells: Ammonites, Nautili, Belemnites. Crustaceans; Echinoderms; Star-fish. Fishes. Bones of Mosasaurus, Ichthyosauri, Plesiosauri, Turtles, and other reptiles. Corals, Sponges, and other zoophytes. Fuci; drift-wood; Cycadeous plants. Almost all the genera and species extinct.
Lower Chalk.	Strata of white limestone; calc-spar, pyrites, seams of marl; quartz pebbles; flints very rarely. Lower beds often grey and argillaceous.	
Firestone.	Beds of marl, passing into calcareous sandstone and sand, full of green particles (*Firestone*). Bands of hard sandy and cherty limestone. Pyrites; chalcedony; often forming the casts of shells.	Shells, &c. as in the chalk; but many species peculiar. Cephalopoda more abundant and diversified. Chimæroid and other fishes. Some layers abound in molluskite.
Galt.	Dark blue clay and marl, with thin layers of red marl; gypsum; pyrites.	Ammonites, Hamites, Belemnites, and other cephalopoda: many species peculiar. Several characteristic shells and crustaceans; drifted coniferous wood.

Greensand.	A triple group of sands, sandstones, limestone, and clay. Bands and concretions of chert. Ironstone, fuller's earth; sulphate of barytes; fibrous gypsum.	Marine shells, many peculiar. Ammonites, Nautili, Scaphites of large size. Fishes; Crustaceans. Iguanodon, Megalosaurus, Plesiosaurus, Turtles, and other reptiles.

These various strata can be studied with facility on the southern coast of the Isle of Wight;* at the northern end of Swanage Bay; and along some parts of the Dorsetshire coast. At Southbourn, on the Sussex shores, the firestone, galt, and greensand, emerge from beneath the white chalk on the north of the Downs; and on the coast of Kent, the same group rises from under the chalk on the south side of the North Downs.

10. Folkstone cliffs.—The relative position of these beds is well displayed at Copt Point, near Folkstone. The Firestone appears as a terrace inland, coming out below the



Lign. 55.—Section at Eastware Bay, near Folkstone.

1. The Upper Chalk. 2. Lower Chalk. 3. Firestone. 4. Galt. 5. Greensand.

chalk marl; the Galt constitutes the immediate face of the cliff, and reposes on the Greensand, which forms the lower

* See Geology of the Isle of Wight, for lists of fossils of the cretaceous series of that district.

part (*Lign.* 55). Eastware Bay, near Folkstone, is celebrated for the beauty and variety of the Galt fossils, which are constantly being washed out of the cliff by the action of the sea.

This series may be traced with more or less distinctness around the denudation of the Wealden, encircling the fresh-water strata. The lowermost member, the Greensand, rises into more importance towards the west; and in Surrey, Hampshire, and western Sussex, forms a line of bold hills, which runs parallel with the chalk downs, and rivals them in altitude; a valley of galt generally intervenes between the sand and chalk, as at Reigate. Along the Kentish coast the three natural subdivisions of the greensand are clearly defined. The upper, or Shanklin sand series, is chiefly made up of ferruginous sands, with ironstone and concretions of chert, and dark clays in the lower part. The middle group is marked by the prevalence of green and grey sand, with bands of calcareous sandstone and cherty limestone, called Kentish rag. The lowermost, or Atherfield series, consists principally of sandy argillaceous beds, with layers of concretionary limestone, containing numerous peculiar fossils. The Shanklin and Atherfield deposits are so named from localities in the Isle of Wight where they are developed in great thickness and extent.*

In the north-east of Ireland the greensand constitutes an important feature; on the Continent it is found accompanying the upper members of the chalk formation, and is well displayed in Saxony, and along the Alps and Carpathian mountains.

11. Cretaceous strata near Maestricht.—In the valley of the Meuse there is a series of strata, the uppermost beds of which contain many shells that occur also in the tertiary; these deposits pass downwards into lime-

* See my Geology of the Isle of Wight for details; chap. vi.

stones with numerous flint nodules, and cretaceous fossils; and these imperceptibly blend with the pure white chalk at the bottom. These strata are well shown on the banks of the Meuse, and fossils may be obtained in abundance from the extensive quarries, which have been worked for ages. St. Peter's Mountain, in which these excavations are situated, is a cape or headland between the Meuse and the Jaar, formed by the extremity of a range of hills which bounds the western side of the river valley. The mountain commences at the distance of a mile south of Maestricht, and extends in a direction towards Liege for about three leagues; it presents an almost perpendicular escarpment towards the Meuse. A section of the hill affords the following succession of strata:—

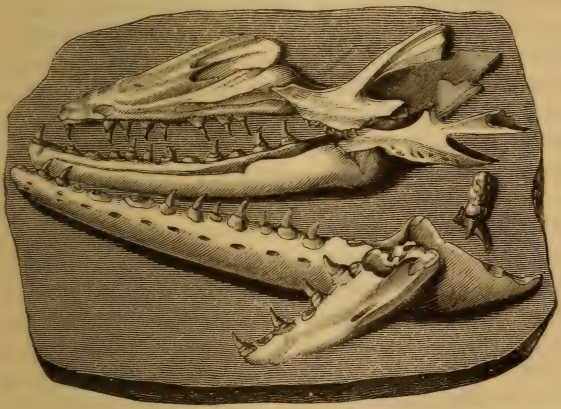
1. Lowermost: *White chalk*, with layers of flint nodules.
2. Chalk, very hard and gritty.
3. *Calcareous freestone*, and beds of loosely aggregated sand, of a yellow fawn colour, abounding in fossils. Numerous layers of flint occur throughout the entire series, having the usual characters of the siliceous nodules of the chalk.

The Maestricht freestone is so extremely soft in the quarry, that it may easily be cut with a knife, but it hardens and becomes of a lighter colour by exposure to the air.* The beds of limestone have a total thickness of about 500 feet. Excavations have for centuries been carried on in the strata of freestone, and from the immense quantities of stone removed, extensive caverns and galleries now traverse the heart of the mountain. Shells, corals,

* The avidity of collectors has induced the quarrymen to practise an ingenious fraud upon strangers: teeth and bones of the horse, boar, &c. are carefully imbedded in blocks of the limestone while it is soft; and when the stone becomes hard, the specimens are offered for sale as genuine fossils from the quarries; the deception may be detected by immersing them in water.

crustacea, teeth of fishes, and other marine remains, occur in profusion; with wood perforated by lithodomi, and the bones of a large and very remarkable reptile.*

12. The mosasaurus; or fossil reptile of the Meuse.—The occasional discovery of bones and teeth of an unknown animal in the limestone, had long since directed the attention of naturalists to the quarries of St. Peter's Mountain. In 1770 M. Hoffmann, who was forming a collection of organic remains, had the good fortune to



Lign. 56.—Remains of the mosasaurus.

Discovered at Maestricht, by M. Hoffmann, in 1770; now in the Museum at Paris.

(Four and a half feet by two and a half.)

discover a specimen, which has conferred additional interest on this locality. Some workmen, on blasting the rock in one of the caverns of the interior of the mountain, perceived,

* See Hist. Nat. de la Montagne de St. Pierre, by Faujas St. Fond, 1 vol. 4to. with splendid engravings, and numerous figures of the fossils that have been discovered in the quarries of St. Peter's Mountain.

to their astonishment, the jaws of an enormous animal attached to the roof of the chasm. The discovery was immediately made known to M. Hoffmann, who repaired to the spot, and for weeks presided over the arduous task of separating from the rock the mass of stone containing these remains. His labours were at length repaid by the successful extrication of the specimen, which he conveyed in triumph to his house. Unfortunately, the Canon of the Cathedral which stands on the mountain, claimed the fossil in right of being lord of the manor, and succeeded, by a most unjust and expensive law-suit, in obtaining this precious relic. It remained in his possession for years, and Hoffmann died without regaining his treasure, or receiving any compensation. The French Revolution broke out, and the armies of the Republic advanced to the gates of Maestricht; the town was bombarded, but by desire of the committee of *savans*, who accompanied the French troops, the artillery was not allowed to play on that part of the city in which the celebrated fossil was known to be contained. In the meanwhile the Canon, shrewdly suspecting why such peculiar favour was shown to his residence, concealed the specimen in a secret vault; but when the city was taken, the French authorities compelled him to give up his ill-gotten prize, which was immediately transmitted to the *Jardin des Plantes*, at Paris, where it still forms one of the most striking objects in that magnificent collection.

The model of this specimen in my museum* was presented to me by Baron Cuvier; it consists of the jaws, teeth, palate-bones, vertebræ, and *os quadratum;* a bone possessed by some reptiles, and in which the auditory cells are contained. There are some fine portions of jaws with teeth of the Mosasaurus in the British Museum. The original was a reptile, holding an intermediate place between

* Now in the British Museum.

the *Monitor* and *Iguana*, about twenty-five feet long; it was furnished with a tail of such construction, as must have rendered it a powerful oar, enabling the animal to stem the waves of the ocean, of which Cuvier supposes it to have been an inhabitant.

In the English chalk a few remains of this reptile have been met with. I collected three vertebræ from the upper chalk near Lewes, many years since;* and have recently obtained a caudal vertebra from Kemp-town, near Brighton; the latter is partially invested with flint, which has consolidated around it without obscuring its essential characters.

Some teeth, from North America, collected by Dr. Morton of Philadelphia, appear to be of the same species as those from Maestricht, and afford additional proof of the extension of the waters of the chalk ocean over the area now occupied by the Atlantic, and part of the dry land of North America.†

13. CRETACEOUS STRATA OF OTHER COUNTRIES.—In the north of France the same characters predominate; but in the south, the group is more or less calcareous throughout; and the lower division, which is the representative of our greensands and clays, consists of calcareous beds, with white limestone and tufaceous marlstone.

In Central and Eastern Germany the entire system is more siliceous, calcareous matter being very sparingly distributed. In Saxony it consists of siliceous sandstone—conglomerates, chert, and ferruginous sand and sandstone—calcareous grit containing the well known galt shell, *Inoceranus concentricus*—and calcareous rock with hamites, scaphites, terebratulæ, and plagiostoma; the uppermost strata yielding a siliceous building stone.

* Fossils of the South-East of England, p. 146.

† See Dr. Morton's Synopsis of the Cretaceous Strata of the United States.

In Russia the white chalk is finely developed in the southern steppes of the Don Cossacks ;* and Artesian wells have been carried to a depth of 630 feet through these strata, without indicating any change of rock. The chalk at Uspensk lies in hollows of the carboniferous system, and contains many well known English cretaceous shells. In the royal collection at Warsaw are echinoderms and shells from the Polish chalk, identical with our common species: even the *Choanites Königi* occurs in the flints, as in those of the South Downs.† Sir R. Murchison observed true chalk on the banks of the river Ural, the extreme boundary of the Russian Empire. On the Volga the white chalk passes through a group of clay-stones and shales, into tertiary eocene strata. The surface of the chalk of Russia is no where eroded as in Western Europe.

In North America, the deposits which appear to be the equivalents of the lower members of the British series, contain numerous fossils of the cretaceous types, and a few species which are identical. The chalk strata of New Jersey, that intervene between the Alleghany mountains and the Atlantic, resemble the sandy and argillaceous beds of our galt and greensand. The overlying tertiary consist of marly clays, and variously coloured sands, with green particles, as in the bottom of the London clay near Reading. Such is for the most part the character of the series in New Jersey : and further south, in Maryland and Virginia, the eocene strata are as full of green particles as the cretaceous, and can only be distinguished by their fossils, and geological position.‡

* Geology of Russia, vol. i. p. 265. All the remarks relating to the Geology of Russia are derived from Sir R. I. Murchison's work.

† Medals, vol. i. p. 264.

‡ See Mr. Lyell's Remarks on the Cretaceous Strata of New Jersey, in his Travels in North America. Also Prof. Rogers's Address to the Association of American Geologists. 1844.

14. Organic remains of the chalk formation.—I would remind the reader, that the numerous groups of strata comprised in the cretaceous system, are to be regarded as an ancient ocean-bed ;—a vast accumulation of sedimentary deposits, more or less consolidated by subsequent chemical changes, that was formed in the profound depths of the sea, in periods of unfathomable antiquity. This mass is made up of inorganic and organic materials : the former consist of the debris of the cliffs and shores which encompassed the ancient sea ; of the spoils of islands and continents brought into the ocean by floods and currents of fresh water ; and of mineral deposits thrown down from chemical solutions: the *organic substances* are the durable remains of animals and plants which lived and died in the ocean, and of fluviatile and terrestrial species that were transported from the land by rivers and their tributaries. The whole forms such an assemblage of sedimentary deposits as would probably be presented to observation, if a mass of the bed of the Atlantic, 2000 feet in thickness, were elevated above the waters, and became dry land ; the only essential difference would be in the generic and specific characters of the imbedded animal and vegetable remains.

The fossils of the cretaceous formation are exceedingly numerous, and offer examples of all the usual forms of marine existence except Cetaceans, of which no vestiges have as yet been found in strata older than the eocene.

Particular genera and species appear, however, to be restricted to certain subdivisions of the system ; thus, in the white chalk, there are many species of shells that do not occur in either of the other groups. The marl and galt also have peculiar fossils, and the greensand abounds in shells and zoophytes, that are wanting in the upper series of deposits. The genera and species of the mollusca must therefore have varied during the period of the deposition of the chalk ; some kinds prevailed at the commencement of the formation, and became extinct, or at least no longer inhabited the same parts of the ocean at a subsequent epoch ; while other forms appear for the first time.

The state of preservation in which the fossils occur, varies according to the lithological composition of the strata. The shells, corals, echinites, &c. of the white chalk, are generally transmuted into carbonate of lime having a spathose structure ; their cavities are commonly filled with chalk, flint, or sulphuret of iron ; in many instances they are hollow, and lined with crystals of carbonate of lime. The softer zoophytes are often silicified, and there is scarcely a flint nodule in which their remains may not be traced. The bones of the reptiles and fishes, and the coverings of the crustaceans, are in a friable state, and stained with sulphuret of iron. The teeth and scales of the fishes possess a high polish, and are more or less permeated by ferruginous infiltrations. Wood occurs in the state of lignite in the clays and sands, and in brown friable masses in the chalk, which quickly decompose upon exposure to the air ; but when enveloped in flint, the structure is silicified, and well preserved ;* like the fossil wood of the tertiary, it has evidently been drifted, and is perforated by teredines and other boring animals ; the fissures are often filled with brilliant pyrites.

In the *Galt*, the nacreous covering of the shells is commonly preserved, and the ammonites and nautili of Folkstone rival in beauty the shells of the London clay, and like them are subject to decomposition.

The *Greensand* fossils in the cherty sandstones are often silicified ; and the whetstone pits of Devonshire are celebrated for the beauty and variety of the chalcedonic shells, star-fish, &c. with which they abound. In the sands, limestones, and argillaceous strata, the shells are for the most part well preserved.

* Medals of Creation, vol. i. p. 168.

The organic remains of the cretaceous system already known, amount to many hundred species. The most striking zoological character, is the abundance of echinites, belemnites, and ammonites : the latter are the shells of an extinct race of cephalopoda, that appears for the last time in the chalk ; no traces of the existence of a single species having been discovered in the tertiary, or any newer formations. My collection, consisting of many thousand fossils from the chalk of England and America, displays the usual genera and species of zoophytes, corals, shells, echinites, star-fish, crinoidea, crustacea, fishes, and reptiles ; together with many that are exceedingly rare, and some unique. I will illustrate this subject by a selection of a few examples.*

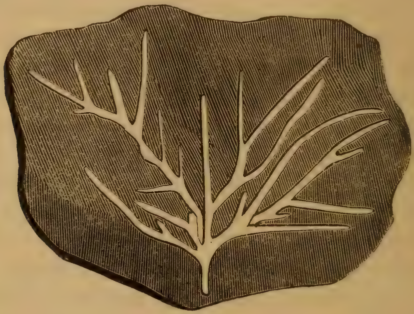
15. Fossil vegetables.—The marine flora of the chalk, as I have already remarked, offers but little variety : a few species of *Fuci*, and *Confervæ*, are the only instances that have come under my notice. One species of Fucus, (*Fucoides Targionii*, *Lign.* 57,) abounds in the malm rock of Western Sussex, particularly at Bignor, formerly the seat of my late friend, John Hawkins, Esq.; almost every fragment of the rock is marked with its meandering forms. *Confervæ* are occasionally found in the flints, and very rarely in the chalk.† Plants allied to *Zostera* occur in the chalk of the Isle d'Aix. Drifted wood abounds in the line of junction between the galt and greensand. In the Kentish rag, near Maidstone, there have been discovered

* I would refer the reader to my Medals of Creation, for details of the most important organic remains of the chalk; and to Mr. Morris's catalogue of British fossils, for lists and references of all the published species. Figures and descriptions of British chalk fossils are given in my Fossils of the South Downs, Wonders of Geology, and Geology of the South-East of England; in Mr. Sowerby's Mineral Conchology, Mr. Lyell's Elements of Geology, and Parkinson's Organic Remains of a Former World.

† *Confervites Woodwardii;* Medals of Creation, vol. i. p. 104.

fir-cones (*Abies Benstedi*), coniferous wood, petioles of the *Clathraria*, and the stem of a plant allied to *Dracæna*.

The *Coniferæ* (cone-bearing, as the Larch) appear to have constituted the principal feature in the flora of the country,



LIGN. 57.—FUCUS IN MALM-ROCK; FROM BIGNOR PARK, SUSSEX.

(Fucoides Targionii.)

whose rivers and streams flowed into that part of the chalk ocean that is accessible to observation in England. All the wood I have met with, whether in the white chalk, fire-stone, galt, or greensand, is coniferous; and most of it possesses the structure of the *Araucaria*, or Norfolk Island pine. Several pine or fir cones have been found, but all of small size.

Of those peculiar coniferous plants, the *Zamia* and *Cycas*, many remains have been collected. A beautiful elongated cone of a Zamia was obtained some years since, near Willingdon, in Sussex, from a bed of greensand, which abounds in coniferous wood.*

In the chalk marl at Bonchurch, in the Isle of Wight, a remarkable specimen of the summit of a stem of the

* It is figured in Geol. Proc. 1843, as *Zamites Sussexiensis*. See Medals of Creation, *Fossil Coniferæ*, vol. i. p. 165.

Clathraria, with the petioles attached, has been discovered ; as this plant essentially belongs to the flora of the Wealden, its description will be given in a subsequent section of this discourse.

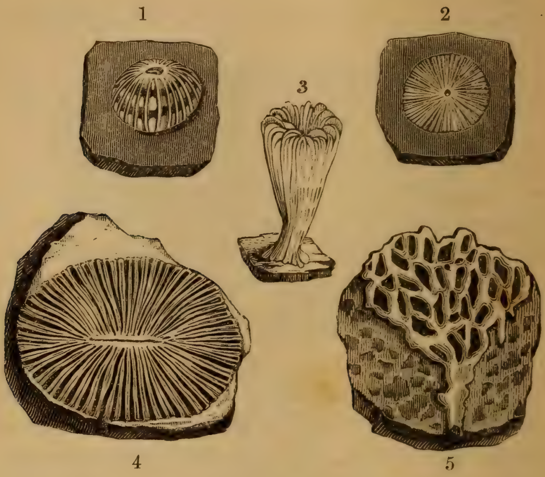
A few imperfect specimens of an oval compressed fruit, have been found in the chalk near Lewes, and in Kent. This fruit, so far as can be judged from the examples known, appears to have been a compound berry, having, like the mulberry, the seeds imbedded in a soft pulpy mass.*

16. FOSSIL ZOOPHYTES.—The soft and flexible zoophytes are so exceedingly numerous in the flints, that but few nodules are destitute of traces of sponges, and other kinds of amorphozoa and porifera. In the white chalk, corals are comparatively rare ; but the Maestricht beds contain them in great abundance. There are certain layers of a very friable earthy chalk in the cliffs along the Kentish coast, and especially near Dover, that abound in very delicate and beautiful species of numerous small corals ; as ***Retepora***, ***Pustulopora***, ***Millepora***, *Idmonea Comptoniana*, &c.† A small *Caryophyllia* (*Lign.* 58, *fig.* 3) is common in the English chalk ; a species of *Turbinolia* (*Lign.* 58, *figs.* 1, 2) in the galt ; and of *Astræa* in the greensand. Specimens have been collected of several other genera ; but the absence of the large madrepores and stony corals is a remarkable fact, corroborating the evidence derived from other sources, that the white chalk was deposited in the profound

* I have named this fruit *Carpolithes Smithiæ*, in honour of Mrs. Smith of Tunbridge Wells ; a lady of consummate skill in the dissection of chalk fossils, and most ardent and liberal in the promotion of palæontological science. Medals of Creation, vol. i. p. 196.

† Medals of Creation, vol. i. p. 284. I have a splendid mass, from Dover, of retepora and pustulopora, covering a surface of chalk, six inches by four ; the chalk itself wholly consisting of an aggregation of polythalamian shells; it was collected by Mrs. Smith, of Tunbridge Wells. Specimens of these chalk corals may be obtained of the dealer, W. Griffiths, of Dover, and 91, Tooley-street, London.

abyss of an ocean; for the economy of the living corals fits them to live only in waters of moderate depths. It would be tedious and uninstructive to place before you



LIGN. 58.—CORALS FROM THE CHALK FORMATION.

Fig. 1. *Turbinolia Königi* from the galt: the fossil is attached to the marl by the disk, the base lying uppermost and exposed. 2. The upper surface of *Turbinolia Königi*, imbedded in galt. 3. *Caryophyllia centralis*, from the chalk near Lewes. 4. *Fungia* in limestone, from Maestricht. 5. *Gorgonia*, from Maestricht.

lists of the scientific names by which the zoophytes of the chalk are known to naturalists; it will suffice to observe, that the more delicate forms, as flustra, millepora, cellepora, retepora,* &c. are very abundant: and in some localities of the greensand, as, for example, the quarries at Faringdon, in Berkshire, the strata literally swarm with various species of spongia, siphonia, &c.;† the nature of these fossils will be explained in a subsequent lecture.

* See Medals of Creation, vol. i. p. 284. † Ibid. p. 256.

There is a fossil zoophyte (*Choanites Königi*) which is well known to collectors of Sussex pebbles by the name of *petrified sea-anemone*, from its supposed resemblance to the living Actinia (*Pl.* VI. *fig.* 11); but the original was a very different creature. From an extensive suite of specimens, I have ascertained that it was of a pyriform shape, with a central opening, from which numerous tubes radiated; and these are oftentimes exquisitely preserved in flint. The external surface frequently exhibits the remains of crucial spines, similar to those possessed by the recent alcyonia.*

Certain polypiferous zoophytes (*Ventriculites*) are exceedingly numerous in the chalk near Lewes and Brighton; and being often preserved partly in chalk and partly in flint, give rise to most interesting specimens, which throw light on the segregation of silex from the thermal streams holding that mineral in solution, which were periodically erupted into the calcareous sediments of the chalk ocean.†

17. Animalculites of the chalk.—Under this head I will notice some of the minute organisms of the cretaceous system. The term animalculites, though not strictly applicable to all the microscopic fossil *Infusoria*, may be conveniently employed to designate the remains of animalcules of the most simple structure; and *polythalamia*, to denote the chambered shells of the foraminifera; as rotalia (p. 249), textilaria, &c.‡

The *Foraminifera* are marine animals, of low organization, and, with but few exceptions, extremely minute; in an ounce of sea-sand between three and four millions

* Thoughts on a Pebble, pl. 1 & 2. Medals of Creation, vol. i. p. 264.

† See Medals of Creation, vol. i. p. 274.

‡ Want of space compels me to refer the reader for many details on this subject, to my "*Notes on a Microscopical Examination of Chalk and Flint,*" in the Annals of Nat. Hist. 1845.

have been enumerated. The body consists of uniform granules, inclosed in a skin or membrane, having one or more cavities or digestive sacs. These animals appear, in fact, to be merely polypes protected by shells; some have a single cell (*Orbulina*): others consist of several cells, disposed in a conical or cylindrical direction (*Nodosaria*). Another family has the shell discoidal like the nautilus, and divided by cells; these are the *polythalamia*, properly so called, of which there are many genera, distinguished by peculiarities in the aperture, disposition of the septa or partitions, and direction of the spire and volutions: to this group belong the Rotalia, Rotalina, Cristellaria, &c. All these forms swarm in infinite multitudes in the present seas, and were not less abundant in the ancient ones. The Nummulites of which we have already spoken (p. 248), have also living representatives (*nummulina* of M. D'Orbigny). The distinguishing character of these shells consists in the numerous perforations by which they are traversed, and which in the living state afforded exit to minute filaments or processes.*

18. Chalk rotaliæ.—In the *Rotaliæ*, which are the most abundant cretaceous forms, the body of the animal is inclosed within the shell, and occupies all the chambers; and the perforations, which are numerous, admit of the exsertion of the soft transparent feelers or pseudo-podia, which are the instruments of motion. The shell of the rotalia, therefore, though presenting the general form of that of the nautilus, is essentially different: for in the latter the body of the animal is wholly contained in the outer chamber, and the internal compartments are successively-quitted empty dwellings; whereas, in the polythalamian, all the cells are filled by the soft parts of the animalcule contemporaneously. When the shell, which is calcareous, is removed by weak hydrochloric acid, the body is exposed,

* See Medals of Creation, vol. i. p. 232.

and is seen to extend to the innermost chamber ; and there is a connecting tube which occupies the place of the siphuncle of the nautilus, for the digestive sacs in the cells are united by the intestinal canal ; minute infusoria which the animal has swallowed, may sometimes be detected in these receptacles. The annexed figure, *Lign.* 59, represents a recent marine polythalamian deprived of its shell.

LIGN. 59.—The body of a recent foraminiferous animalcule: the shell having been dissolved by acid. From the North Sea, off Cuxhaven.

(*Nonionina Germanica*, of Ehrenberg ;)

Magnified 200 *diameters*.

In some of the sacs (*a*, *a*,) Naviculæ and other infusoria swallowed by the animal are visible. *From Ehrenberg's Memoirs*.

A comparison of this figure, with the specimen in flint (*Lign.* 51, p. 303), will show the close analogy between them.

The soft parts of these foraminifera occur, not only in the flint, but in the white chalk : and by subjecting the latter to the action of dilute hydrochloric acid, the bodies of the rotaliæ may sometimes be detected, as distinct in form, as in this recent specimen from the sea (*Lign.* 59). I must refer to my observations on this subject in the Philosophical Transactions (for 1846, part iv. p. 465), for further particulars of this remarkable fact. The Rotaliæ and Textilariæ are the prevalent foraminifera in the English chalk : and the same species swarm in our seas, and are abundant in the sandy clays which are spread over great part of Cambridgeshire, Lincolnshire, &c. Mr. Williamson of Manchester, and Mr. Smith of March, have sent me specimens of this sand, principally made up of these shells, with those of *Lagenula*, *Spiroloculina*, &c.*

The common generic forms of the English chalk, and some of the species, have been found in the cretaceous strata throughout Europe, Asia, and America. From numerous localities of America I have obtained, through the liberality of Dr. Bailey,† earths largely composed of these fossils. Mr. Lyell has figured, from the cretaceous beds of New Jersey, a Rotalina and Cristellaria, identical with English species.‡

19. CHALK DETRITUS AT CHARING.—I must conclude this notice of the cretaceous polythalamia, by directing attention to a remarkable deposit, first observed by W. Harris, Esq. of Charing, Kent, to whom I am indebted for an extensive suite of the prevalent species. Near Charing, there is a bed about a foot thick of chalk detritus, consisting of white sandy tenacious clay, spread over the outcrop, or exposed surface of the firestone ; and which has evidently originated from the action of water on the unconsolidated chalk of the neighbouring downs, before the surface of those hills was protected by a covering of vegetable soil. This debris is largely made up of shells of numerous kinds of

* See a highly interesting paper on Foraminifera from the Levant, Boston, and Charing, by W. C. Williamson, Esq. in vol. viii. of the Manchester Literary and Philosophical Society, 1847.

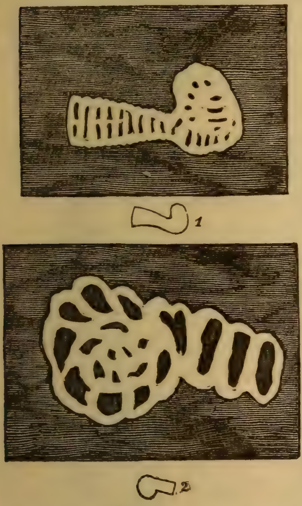
† Dr. W. Bailey, Professor of Chemistry in the U. S. Military Academy of West Point, New York, a gentleman eminently distinguished for his scientific attainments, has elaborately investigated the fossil infusoria and foraminifera of the United States, and published the result of his researches in several successive numbers of the American Journal of Science.

‡ Geol. Proc. for 1845-6, p. 4.

foraminifera and infusoria, with spines of sponges, and a considerable intermixture of polygonal spicula, resulting from the decomposition of the large fibrous bivalve termed *Inoceramus*, so common in the chalk. Intermingled with the decidedly cretaceous forms, are minute fresh-water shells, which have probably been derived from some modern deposit; and many shields or cases of small marine crustaceans, termed *Cytherina;* which are related to the Cyprides.*

20. Spirolinites.—The chalk and flints often contain beautiful examples of a foraminiferous chambered shell, of a crosier-like form, termed *Spirolinites;* of which several species were discovered some years since, by the Marquess of Northampton. I subjoin enlarged figures of two species (*Lign.* 60); and the following communication, with which I have been honoured by his Lordship.

"I willingly comply with your desire to communicate a short note on the Sussex *Spirolinites*, one species of which you have been pleased to distinguish by my name. I have found these fossils in flint at Brighton, Kemptown, Rottingdean, Lewes, Hastings, Steyning, Chichester, West Stoke, and in the Isle of Wight; and one specimen in France. I have discovered about two hundred of these minute chambered



Lign. 60.—Spirolinites in flint; *from the South Downs.*
Fig. 1. Spirolinites Lyellii.
2. S. Murchisoni.

* The only notice of the Charing animalculites, is contained in Mr. Williamson's memoir above referred to. It is to be hoped the intelligent and liberal discoverer, Mr. Harris, will publish a full account of the geological relations and organic contents of this curious deposit.

shells in flint, but only two in chalk. The specimens which I have collected constitute four distinct species. 1. The one to which you have been pleased to give the appellation of *S. Comptoni.* 2. *Spirolinites Lyellii,* distinguished by the horizontal chambers one above the other, in the coiled portion. 3. *S. Stokesii,* which I name after our friend Charles Stokes, Esq.; and this name has the further advantage of pointing out the locality, West Stoke, near Chichester, from which I obtained this unique specimen, and where other spirolinites abound. The fourth you must allow me to designate *S. Mantelli.* The distinctive characters of these species are too obvious to require detailed description. The transverse chambers in *S. Lyellii* (*Lign.* 60, *fig.* 1) are a striking peculiarity of structure. I am inclined to believe that there are other species in my collection, but the irregularity in the fractured sections of these minute chambered shells, renders it difficult to arrive at accurate conclusions on this point. "Northampton."

"*Castle Ashby, January* 1, 1838."

21. Crinoidea.—The *Crinoidea,* or lily-shaped animals, are but sparingly distributed in the chalk—a circumstance, as you will hereafter find, in striking contrast with the zoological characters of some of the older secondary formations. Stems of *Pentacrinites* occur both in the chalk and galt; and there is a small species of *Apiocrinite,* which is peculiar to the white chalk.*

Lign. 61.
Marsupites Milleri; *from the chalk, Brighton.*

A remarkable cretaceous fossil of this class is the *Marsupite,* which I thus named from its resemblance, when closed, to a purse. The Marsupite (*Lign.* 61) was a crinoideal animal, of a sub-ovate form, having the mouth, which was surrounded by arms, or tentacula, near the centre. The skeleton was composed of crustaceous, hexagonal plates, united by suture, and the arms, which are

* Geology of the South-East of England, p. 111.

subdivided into a few branches, were formed of little bones, or *ossicula*; the whole was invested with a muscular tissue, or membrane. When floating, the creature could spread out its tentacula like a net, and by closing them, seize its prey and convey it to the mouth. This figure (*Lign.* 61) is restored from specimens which separately exhibit the parts here represented.*

22. Star-fishes of the chalk.†—Of the radiated animals termed *Asterias*, or star-fish, several genera occur in the English chalk and greensand, and in the cretaceous strata of the Continent. In the Sussex chalk, beautiful examples of the *Goniaster*, or cushion-star, have been found; but they are more frequently met with in the white chalk near Gravesend, Northfleet, Purfleet, and other Kentish localities. The cabinet of the Marquess of Northampton contains exquisite specimens of Goniaster, partly imbedded in flint; similar fossils have been obtained from the siliceous rock, called *whetstone*, of Devonshire. Several fine examples of an undescribed Asterias of the radiated type, with elongated rays, and large ossicula, have been collected from the Dover chalk: and a splendid specimen from that locality, as perfect as if recently dredged up from the sea, is in the beautiful collection of Mrs. Smith, of Tunbridge Wells. Detached ossicula are very abundant in some of the strata; and there are layers of the grey or lower chalk, wholly made up of the debris of star-fish, minute spines of echini, &c.

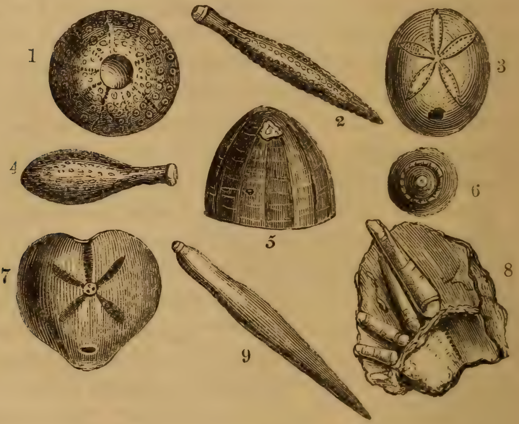
23. Echinites.‡—Those remarkable animals, the Echini, or sea-urchins, are too well known to require particular description. Their spherical shell, or case, is composed of

* There is another species often found with the above, in which the plates are covered with rugous markings; it is the *M. ornatus* of the late Mr. Miller.

† Medals of Creation, vol. i. p. 332.

‡ See Medals of Creation, vol. i. chap. xi. p. 340.

polygonal plates, closely fitted to each other; and the surface is divided vertically by bands, like the meridians of a globe, having rows of double perforations. The shell is studded over with papillæ, which vary in size, in the different species, from mere granular points to large well-defined tubercles. To these papillæ, spines are attached, which also present great variety of figure and decoration;* these are the instruments of motion, and as on the death



Lign. 62.—Echinites and spines, from the chalk.

(*Figs.* 5, 7, *one-third less than the originals.*)

Fig. 1. Cidaris diadema. 2, 4, 9. Spines of Cidaris. 3. Nucleolites. 5. Ananchytes ovatus. 6. A tubercle of a Cidaris. 7. Spatangus cor marinum. 8. Spines and portion of the shell of a Cidaris in flint.

of the animal, the tendons by which they were fixed to the shell decompose, the rarity of fossil specimens, with these processes attached in their natural position, is readily explained. The Echini, both recent and fossil, comprise a

* Medals of Creation, vol. i. p. 348.

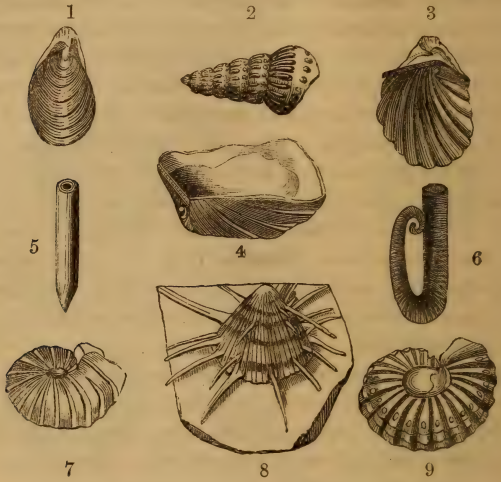
great variety of species, which are arranged in numerous sub-genera, for the convenience of study; but I can notice only a few of the common forms.

The helmet-shaped echinites (*Lign.* 62, *fig.* 5) are extremely abundant, and in some localities occur in shoals, and in every gradation from the young to the adult state. Siliceous casts, formed by the decomposition and removal of the shell from the flint with which it was filled, are common in gravel and on ploughed lands. The cordiform variety (*fig.* 7) is very abundant, and gives rise to the heart-shaped flints of our gravel-pits. The elliptical species (*fig.* 3) is common in the greensand. The turbinated echini (*Cidares*), are beautifully embossed with papillæ: a small species (*fig.* 1) is frequent in the chalk and flints of Kent; the larger varieties possess tubercles (*fig.* 6), surrounded by elegant margins, and are otherwise richly ornamented. Some spines are slender, and covered with asperities (*fig.* 2); others almost smooth (*fig.* 9), and club-shaped (*fig.* 4); it is not often that spines are found in contact with the shell (*fig.* 8), this however, is occasionally the case, and from the chalk at Gravesend, and other localities in Kent, splendid examples have been discovered; some with groups of large spines attached to the tubercles, as in the living state.

24. Shells of the chalk.—The bivalve shells, or conchifera of the chalk, are very numerous; of one genus alone (*Terebratula*), above fifty species are enumerated. Oysters, scallops, arcas, tellens, and other familiar marine shells abound, but the species differ from the recent. With these known genera are many which, so far as our present knowledge of the inhabitants of the deep extends, are extinct. Two or three species of *Cirrus* are not unusual in the English white chalk; but the univalves are few; and the only specimen of a large simple spiral univalve with which I am acquainted is a species of *Dolium*, of which several

specimens have been collected from the marl at Clayton Hill, Sussex.*

The Maestricht beds, as before remarked, contain many fossils not found in the other chalk strata. A large *Volute* (*V. Faujasii*) occurs in the flint nodules of St. Peter's



LIGN. 63.—SHELLS FROM THE CHALK FORMATION.

Fig. 1. Inoceramus concentricus; from *Galt.*
2. Turrilites costatus; *Chalk-marl.*
3. Inoceramus sulcatus; *Galt.*
4. Inoceramus Lamarckii; *White-chalk.*
5. Belemnites Listeri; *Galt.*
6. Hamites; *Galt.*
7. Ammonites Mantelli; *Chalk-marl.*
8. Plagiostoma spinosum; *White-chalk.*
9. Ammonites Sussexiensis; *Chalk-marl.*

Mountain, with baculites, ammonites, and other characteristic chalk fossils. In the marl at Hamsey, near Lewes, I have discovered a few genera of univalves not previously known in the chalk.

* Mineral Conchology, vol. v. tab. 426.

The sub-globular terebratulæ, both the common and the striated varieties, are very abundant.* Another bivalve equally numerous, is an elegant shell, having one valve covered with long spines (*Lign.* 63, *fig.* 8), the *Plagiostoma spinosum.*† A bivalve with a fibrous structure (*Inoceramus, Lign.* 63, *fig.* 4), very brittle, and having a crenulated hinge of a peculiar construction, presents numerous species; some of which are small and delicately striated, while others are two feet in diameter, and deeply furrowed.‡ The substance of these shells closely resembles in structure that of the recent *pinnæ;* and from its fragility, fragments are very common in chalk, flint, and even in pyrites.§ The *Galt* contains two species of this genus, which have been found in almost every locality, and appear to be restricted to this division of the chalk; they are the *Inoceramus concentricus* (*Lign.* 63, *fig.* 1), and *I. sulcatus* (*fig.* 3); a hybrid occurs in the Folkstone beds, partaking of the characters of both. I have discovered a species of *Spherulite (S. Mortoni)* in the chalk near Lewes, in Sussex; but *Hippurites,* so common in the cretaceous strata of the Continent, have not been noticed.||

The shells of the Marl, Galt, and Greensand, amount to many hundred species: those of the whetstone pits of Blackdown, in Devonshire, being completely silicified, and changed into silex, jasper, or chalcedony.¶

* Medals of Creation, vol. i. p. 379.

† This shell was formerly supposed to be peculiar to the chalk strata, but specimens have been discovered by Mr. Pratt in eocene deposits. Medals of Creation, vol. i. p. 390.

‡ Ibid. p. 393. § Ibid. p. 396.

|| Ibid. p. 428. No true *Hippurites* have been found in the English chalk; the shells of the family Rudistes hitherto met with have the characters assigned to the genus *Spherulites.*

¶ The shells of the cretaceous formation are most fully described and figured in M. D'Orbigny's beautiful work on the fossils of France —Palæontologie Française.

25. CEPHALOPODA OF THE CHALK.—The most striking feature in the marine fauna of the chalk, as contrasted with that of the tertiary and modern formations, is the great preponderance of multilocular cephalopoda.* In the tertiary, and existing tropical seas, one genus (the *Nautilus*) occurs abundantly. The beauty, elegant form, and remarkable internal structure of the recent shell, have rendered it in all ages an object of admiration; yet an accurate knowledge of the organization of the animal to which it belongs, has but recently been obtained. The Nautilus, and the allied fossil genera, may be regarded as Sepiæ or Cuttle-fish inhabiting chambered shells, which are furnished with an apparatus to impart buoyancy, and enable the animals to swim on the surface, or sink to the depths of the ocean at pleasure.

A few remarks on the recent types will serve to render the subject intelligible. The *Sepia*, or *Cuttle-fish* of our seas is of an oblong form, composed of a jelly-like substance, covered with a tough skin; the mouth, which is central, is furnished with horny mandibles, much resembling the beaks of a parrot. The animal has two large eyes, and eight arms studded with rows of little cups, or suckers, which are powerful instruments both of locomotion and prehension. The soft body of the sepia is supported by a skeleton, formed of a single bone or *osselet* of a very curious structure; when dried and reduced to powder it is the substance called *pounce*. The Cuttle-fish has a membranous sac, which secretes and retains a dark-coloured fluid, resembling ink; this the animal can eject when pursued, and by thus rendering the water turbid, escape from its enemies. This fluid, properly prepared, forms the colour termed *sepia*, which is so much employed in the arts.

* See Medals of Creation, vol. ii. p. 456, for an account of the Cephalopoda.

26. The nautilus.—The shell of the Nautilus consists internally of a series of chambers, pierced through the middle by a siphunculus or tube, which extends to the remotest cell. The body of the animal resembles, in some respects, that of the sepia, and is contained in the outer receptacle of the shell ; it maintains a connexion with the inner chambers by means of a membranous tube which lines the siphuncle. The internal chambers are air-cells, and the creature has the power of filling the siphuncle only, with a fluid secreted for the purpose, and also of exhausting it ; and the difference thus effected in the specific gravity of the animal and its shell, enables the Nautilus to sink or swim at pleasure. If, therefore, you imagine a cuttle-fish placed, with its arms extended, in the outer chamber of a nautilus-shell, and provided with a tube connected with the siphunculus, but having neither ink-bag nor osselet, these being unnecessary to an animal with the protection and mechanism of a chambered shell, you will have a tolerably correct idea of the recent Nautilus. The Nautilus is essentially a ground-dwelling animal, living in deep water, and feeding on the marine plants which grow at the bottom of the sea. Rumphius states that it creeps with the shell above, and that by means of its tentacula it can make quick progress along the ground.* There are several species of Nautilus in the chalk, some of which are of large size: a common marl species is figured in *Lign.* 64.

Lign. 64.—Nautilus elegans; from the Chalk-marl, near Lewes.
(*One-sixth the natural size.*)

* See Medals of Creation, vol. ii. p. 482.

27. THE AMMONITE, OR CORNU AMMONIS.—The fossils called Ammonites, first appear in the secondary formations; or more properly, no traces of their remains have been found in the tertiary or any later deposits. The Ammonite, so called from its supposed resemblance to the horn of Jupiter Ammon, is a fossil chambered shell, coiled up in the form of a disk, bearing a close analogy to the nautilus, but differing in the situation of the siphunculus, and in the septa by which the interior is divided. In the Nautilus these partitions are entire, and their section presents a series of simple curves ; but in the Ammonite they are very sinuous, and the external surface of the casts commonly exhibits markings resembling the outlines of deeply fringed foliage ; the shell is also generally decorated with flutings, ribs, or tubercles. The siphuncle, or syphon, which in the Nautilus is central, is situated at the back, in the Ammonite. I have placed before you examples from the Galt of Folkstone, in which the shell remains,—from Watchett and Hartwell, with the internal nacreous coat only,—while in this common species from Whitby (*Lign.* 65), the shell is altogether wanting, the specimen being a cast of the interior, formed of argillaceous iron-stone ; a state in which these fossils are frequently found.

LIGN. 65.—AMMONITES COMMUNIS;
from the Lias of Whitby.

In some examples, the shells and partitions of the chambers having decomposed, casts of the cells have been formed, which fit into each other, and admit of being put together, so as to show the entire shape of the ammonite. Many hundred kinds of Ammonites are known in the secondary formations, and certain species are restricted to particular rocks. Thus, for example, the chalk marl of Sussex abounds in two species (*Lign.* 63, *figs.* 7, 9), which very rarely occur either in the chalk above, or in the galt below; and in every locality of the marl in England, and on the Continent, these have been met with.* The membranous tube of the siphuncle sometimes occurs in a fossil state, as may be seen in this ammonite from the chalk marl near Lewes, in which a large portion remains; the black substance of these tubes has been analyzed, and found to consist of animal membrane, permeated by carbonate of lime.†

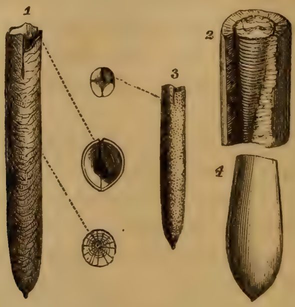
Ammonites vary in size from a few lines to twelve or fourteen feet in circumference; at low water on those parts of the Sussex coast where the chalk forms the base of the shore, enormous specimens are often seen imbedded. In some of the marls and clays of the chalk, hundreds of ammonites occur in clusters.

28. Turrilite, hamite, &c.—*Baculites*, *Turrilites*, *Hamites*, *Scaphites*, and other genera of multilocular shells, abound in the chalk-marl, galt, and greensand. The turrilite (*Lign.* 63, *fig.* 2), may be described as an ammonite twisted in a spiral, instead of a discoidal form: and the hamite (*Lign.* 63, *fig.* 6), as a similar structure in the shape of a hook, coiled up at the smaller extremity. These shells sometimes attain a large size; the turrilite before you,

* See my Fossils of the South Downs, for figures of many chalk Ammonites: also Mineral Conchology; Geological Journal; Medals of Creation, vol. ii. p. 489; and M. D'Orbigny's Palæontologie.

† Dr. Prout is of opinion that the black colour has originated from decomposition; the oxygen and hydrogen of the animal membrane having escaped, and carbon evolved, as happens when vegetable matter is converted into coal, under the process of mineralization. The lime has taken the place of the oxygen and hydrogen, which existed in the pipe before decomposition.—*Dr. Buckland's Bridgewater Essay*, p. 352.

which is the finest example known, would, if perfect, exceed two feet in length; it possesses traces of the siphuncle. Very large hamites and scaphites have been found in the greensand of Kent, Isle of Wight, and other places. The first specimens of turrilites, hamites, and scaphites, from the British strata, were discovered in my early researches, in Hamsey marl-pits, near Lewes.*



LIGN. 66.—BELEMNITES; *one-third natural size.*

Fig. 1. *Belemnitella mucronata*;† from chalk, Brighton. On the right of the figure is a view of the aperture; and beneath it a transverse section of the belemnite, showing the radiated structure.
2. Portion of a Belemnite containing the internal chambered shell, called the *phragmocone.*
3. *Belemnitella quadrata*; from Beauvais, France; the quadrangular cavity is shown in the upper figure on the left.
4. *Belemnites dilatatus*; from the Greensand, France.

29. THE BELEMNITE.—Among the innumerable relics of marine animals which occur in the secondary deposits,

* See Sowerby's Mineral Conchology, vol. i. tab. 18. From the recent cuttings through the chalk-marl at Offham, in forming the railway from near Keymer, through Lewes, to Newhaven, I obtained a fine series of all these genera. Figures of Turrilites, Scaphites, &c., are given in Medals of Creation, vol. ii. pp. 502, 504.

† See Medals of Creation, vol. ii. p. 462. *Belemnitella* is the generic name of the belemnites having a fissure down the front of the alveolus, or cavity which receives the phragmocone.

there are none that have excited so much curiosity, and given rise to so many conjectures as to their nature and origin, as the fossils termed *Belemnites* by geologists, and which are generally known as *thunderbolts.* These are long, cylindrical, or fusiform stones, more or less pointed at one extremity, and having at the other and larger end a conical cavity, which is either occupied by a chambered shell, or filled up with the clay, sand, or stone, in which the belemnite happens to be imbedded. The substance of these bodies is invariably calcareous spar, of a radiated structure (*Lign.* 66, *fig.* 1). Such are the usual characters of these fossils, of which there are numerous species; certain forms abounding in the cretaceous strata. A very common chalk belemnite is figured *Lign.* 66, *fig.* 1; and a peculiarly transparent species from the Galt, *Lign.* 63, *fig.* 5. These bodies were the osselets of cephalopods allied to the *Sepia*, which possessed an ink-bag, mandibles, large eyes, and arms furnished with acetabula or suckers, and slender, elongated, hooks.*

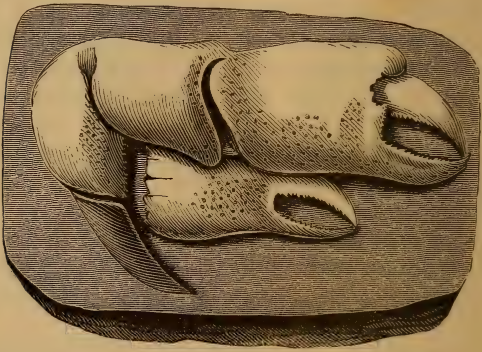
30. CRUSTACEANS OF THE CHALK.† — Specimens of several genera of crustaceans have been obtained from the Sussex chalk; among these are three or four species of *Astacus* or Lobster, in which the filiform antennæ, the abdominal segments, and the caudal appendage, or tail, are preserved.‡

In the Galt, the crustaceans hitherto discovered belong to very small species. I have obtained from Ringmer, near Lewes, and Folkstone, specimens of several extinct forms, which are related to Indian genera. § In the Speeton clay of Yorkshire, Professor Phillips has discovered a beautiful species of Crayfish. ‖ The greensand of Kent, Dorsetshire, and the Isle of Wight, has

* Medals of Creation, vol. ii. p. 469. † Ibid. p. 536.
‡ Ibid. p. 537. § Ibid. p. 532. ‖ Ibid. p. 540.

yielded many remains of this family ; the strata at Atherfield, especially, abound in several species of Lobster.*

In the limestone of St. Peter's Mountain, the claws of a small species of Crab are frequently discovered (*Lign.* 67), but without any other vestiges of the animal. M. Faujas St. Fond, and Latreille, have very ingeniously explained this



Lign. 67.—Claws of a fossil hermit-crab; from Maestricht.

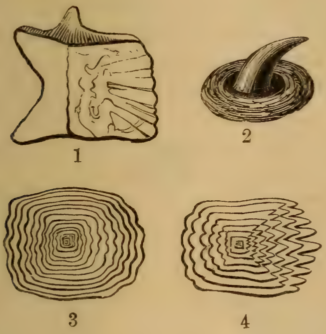
(Pagurus Faujasii.)

fact, by showing that these remains belonged to a parasitical species of *Pagurus*, which, like the common hermit-crab of our seas, had the body covered by a delicate membrane, the claws alone having a shelly case ; hence the latter might be found in a fossil state, while of the other parts of the crustacean no traces would remain.

31. Fishes of the chalk.—The fossil fishes of the white chalk were known only by the teeth, which abound

* Some of the layers of the greensand at Atherfield contain so many remains of two or three species of small Astaci, as to be termed the "*Lobster beds.*" See my Geology of the Isle of Wight, pp. 225, 232 : and the vignette of the title-page of that volume.

in almost every quarry, until my researches in the chalk-pits around Lewes brought to light many extraordinary specimens, and showed how such delicate remains could be developed.* Professor Agassiz, by whose genius and labours this department of palæontology has been most successfully elucidated, has adopted a classification of fishes, founded upon the peculiar structure of the scales—a method of



LIGN. 68.—SCALES OF THE FOUR ORDERS OF FISHES.

Fig. 1. Scale of *Lepidotus*; a fish of the *Ganoid* order.
2. — *Ray*; —— *Placoid* — .
3. — *Salmon*; —— *Cycloid* — .
4. — *Beryx*; —— *Ctenoid* — .

great utility to the geologist, since the mutilated state in which the fossil remains of fishes generally occur, often renders futile all attempts to refer them to the orders and genera of other systems of Ichthyology.†

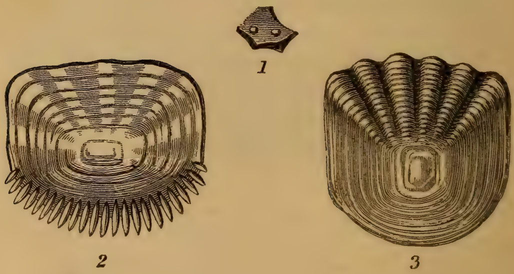
32. SCALES OF FISHES.—M. Agassiz includes all fishes

* I believe the Fossils of the South Downs (1822) contained the first published figures of fishes from the English chalk.

† Recherches sur les Poissons Fossiles, par Louis Agassiz: five vols. folio of coloured figures, and two quarto vols. of letter press.

in four orders, which are distinguished by the structure of the scales, as exemplified in the following tables (*Lign.* 68).

Order I. The *Placoid;* the skin covered with irregular enamelled plates, as in the Rays, Sharks (*Lign.* 68, *fig.* 2).
II. The *Ganoid;* the scales of an angular form, and composed of plates of horn or bone covered with a thick layer of enamel; as in the Sturgeon (*Lign.* 68, *fig.* 1).
III. The *Ctenoid;* the scales formed of plates, which are toothed or pectinated on their posterior margin or edge, like a comb; as in the Perch (*Lign.* 68, *fig.* 4).
IV. The *Cycloid;* the scales composed of simple laminæ of horn or bone, without enamel, and having smooth borders; as in the *Salmon* (*Lign.* 68, *fig.* 3).*



LIGN. 69.—SCALES OF FISHES IN FLINT.

Fig. 1. A fragment of flint containing two scales, of the natural size.
2. One of the scales highly magnified; it belongs to the species of *Beryx*, figured in *Lign.* 68.
3. The other scale highly magnified; it belongs to the species of *Smelt*, figured in *Lign.* 72, *fig.* 1.

Patches of scales are very abundant in some of the white chalk strata in Sussex and Kent; and occasionally very perfect examples of the entire body of the fish, with the fins attached, are obtained; which by proper dissection may be

* See Medals of Creation, vol. ii. p. 593.

beautifully displayed.* Scales and teeth are occasionally found in flint; sometimes adherent to the surface, and in other instances imbedded in the stone. A fragment of flint to which two minute scales are attached is figured in *Lign.* 69, *fig.* 1; and the scales, highly magnified, are represented in *figs.* 2 and 3.

33. Teeth of sharks, &c.—Teeth of several genera of fishes abound in the cretaceous deposits: and of these, by far the greater number belong to the Sharks; a family which in the ancient, as well as in the modern seas, appears to have been confined by no geographical limits. A group of some of the usual forms is represented in *Lign.* 70. These teeth possess a high polish, and are in an excellent state of preservation; they generally occur detached, owing to the decomposition of the jaws, which from their cartilaginous nature are but seldom preserved. A few specimens of the fishes termed *Hybodus*,† have, however, been found with several rows of teeth attached to the jaws.

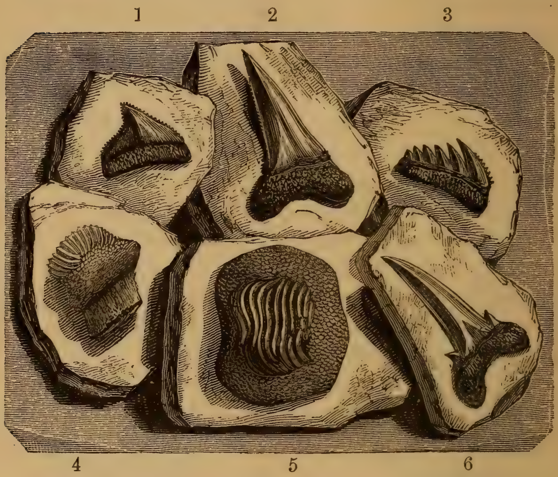
Large flat teeth, having a series of deep angular plaitings on the crown, surrounded by a border of papillæ (*Lign.* 70, *figs.* 4, 5), are very abundant, and are commonly known as "palates." They belong to a genus of the shark family called *Ptychodus* (rugous teeth), allied to the *Cestracion* or *Port Jackson Shark*. A group of teeth has lately been found in the chalk by the Marquess of Northampton, which differ but little from those of the recent living species. Dorsal rays, or fin-bones, belonging to these fishes are occasionally met with in the chalk; the first known examples were figured in my Fossils of the South Downs (*Tab.* 39).‡

* For directions how to clear chalk fishes, see Medals of Creation, vol. ii. p. 673. All my best specimens, most of which are figured in the work of M. Agassiz, are now in the British Museum.

† Medals of Creation, vol. ii. p. 609; Geology of the Isle of Wight, p. 233.

‡ Medals of Creation, vol. ii. p. 605.

Several dorsal spines of a Shark allied to the Dog-fish (*Acanthias*) of our coasts, were found in the same quarries.* Vertebræ, and other remains of sharks, have been obtained



LIGN. 70.—TEETH OF SHARKS; FROM THE CHALK NEAR LEWES.

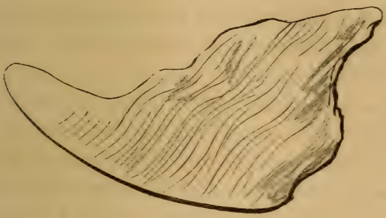
Fig. 1. Galeus pristodontus. 2. Lamna crassidens.
3. Notidanus microdon. 4. Ptychodus polygurus.
5. Ptychodus polygurus. 6. Lamna elegans.

in considerable numbers from the chalk of the south-east of England.

The mandible, or anterior part of the maxillary bone of a fish belonging to a very remarkable family, of which the *Chimæra* is the only living type,† was found in the chalk marl at Hamsey, near Lewes, many years since, associated with turrilites, hamites, &c. and subsequently examples of

* Medals of Creation, vol. ii. p. 609. † Ibid. p. 619.

many other forms have been discovered in secondary and tertiary strata ; thus affording evidence that the ancient seas were inhabited by several genera of this curious and now limited group.*



LIGN. 71.—MAXILLARY BONE OF A FISH ALLIED TO THE CHIMÆRA; FROM THE CHALK NEAR LEWES.

(Endaphodon Mantelli; half the natural size.)

34. HYPSODON.—Teeth of large fishes, belonging to that division called *Sauroid*, from their combining in their structure certain characters of reptiles,† have been found in the white chalk, galt, and greensand. They are of a conical form, longitudinally striated externally, and bearing a general resemblance to those of crocodiles, for which they were formerly mistaken. Remains of several other large fishes are preserved in various private collections, but have not yet been scientifically examined.

There is however a genus of extinct fishes, allied to the Pikes, which has been established by M. Agassiz from some vertebræ and other bones. It is named *Hypsodon*, from the straight and pointed form of the teeth. A jaw with teeth, some vertebræ, and the *os hyoides*, of this fish

* Sir P. G. Egerton has very recently laid before the Geological Society an admirable memoir on the fossil Chimæroid fishes.

† Medals of Creation, vol. ii. p. 650.

were first discovered in the chalk near Lewes, and are figured in Pl. xlii. of my Fossils of the South Downs. Their reptilian character led me to consider them as belonging to a saurian, until I obtained a considerable portion of the cranium, jaws with teeth, the bone that articulates the lower jaw with the skull, and several biconcave vertebræ, imbedded in a block of chalk, and belonging to the same individual.*

35. FOSSIL SALMON. (*Lign.* 72. *fig.* 1.)—Of the cycloid order, or fishes with scales of a cycloid or circular form and smooth margins, and composed of plates of horn or bone without enamel, there are two or three species belonging to the Salmon family, which occur in the lower chalk near Lewes. These ichthyolites are exceedingly beautiful, and generally have the body uncompressed, and as round and perfect as when the fishes were alive. The entire cranium, opercula, branchial rays, and fins, are preserved in some examples. From the close affinity of these fishes to the Smelt (*Osmerus*), they have been named *Osmeroides*. In one specimen I succeeded in clearing away the chalk, so as to expose the entire fish, which lies six inches in relief, being attached by the back to the block of stone; the mouth is open, and the opercula, or gill-covers, and the branchial arches are expanded; the pectoral, dorsal, and ventral fins are in their natural position.†

Even to those whose curiosity has not previously been awakened by the Wonders of Geology, the examination of these petrified inhabitants of the ancient chalk ocean can-

* This fine specimen is now in the British Museum, with other remains of the Hypsodon.

A splendid specimen of jaws and premaxillary bones, with numerous teeth, that differ from the Hypsodon Lewesiensis in being slightly curved, is in the choice collection of Toulmin Smith, Esq. of Highgate. Two species of Hypsodon have been identified in the London clay.

† Medals of Creation, vol. ii. p. 663.

not fail to excite deep interest; and I have often seen the man of fashion, as well as the philosopher, gaze in mute astonishment on these "relics of a former world."

36. Macropoma. (*Lign.* 73. *fig.* 2.)—A fish, bearing some semblance to the large Carps in its general outline, but essentially differing in its structure, is the most remarkable ichthyolite which my researches in the chalk quarries around Lewes, have brought to light;* but it was not till after many years of persevering research that the nature of the original was fully illustrated. This fish when at maturity must have exceeded two feet in length: its skeleton is massy, indicating a powerful frame; and its thick scales, strong fins, and sharp teeth, show that it was a voracious animal, capable of pursuing and overtaking live prey. The head is very large; being nearly equal to one-fourth the length of the body. The scales are large, and are covered on the exposed surface with pointed elongated cylinders. The opercula are very long.† The rays of the fins are large and rigid, especially those of the anterior dorsal, which are armed on each side with rows of sharp spines. The tail is very large, rounded, and fan-shaped, with strong equal rays, supported by the inferior and superior spinous processes of the caudal vertebræ. The form of the jaws and teeth is also remarkable, but my limits will not admit of further details. In every example I have found the remains of what I supposed to be the air-bladder, but which M. Agassiz affirms to be the stomach. It is an oblong cylindrical body, apparently terminating at one end in a cul-de-sac: its surface

* Fossils of the South Downs. It is described under the name of *Amia Lewesiensis.* The largest specimen therein figured (Pl. 38) I presented to Baron Cuvier, and it is now in the museum of the Jardin des Plantes.

† Whence the name *Macropoma; μακρὸς, long,* and *πῶμα, operculum.*

has a squamous appearance, owing to the separation and partial exfoliation of the membranes of which its walls are composed. Under the microscope, the ramification of the vessels through these tissues is distinctly seen. *Coprolites* (or fossil excrements), having a slightly convoluted form, are often found with the remains of the Macropoma.*

37. BERYX; AND OTHER FISHES OF THE CHALK.—It would require a separate work to notice in detail even my own discoveries in this division of the fauna of the chalk ocean, which comprise more than forty species. I must content myself with briefly noticing some of the most interesting examples, and referring to M. Agassiz's splendid volume, in which all the chalk fishes known at the time of its publication are beautifully figured, and philosophically interpreted. But so rapid has been the progress of discovery that many new genera have since been brought to light.

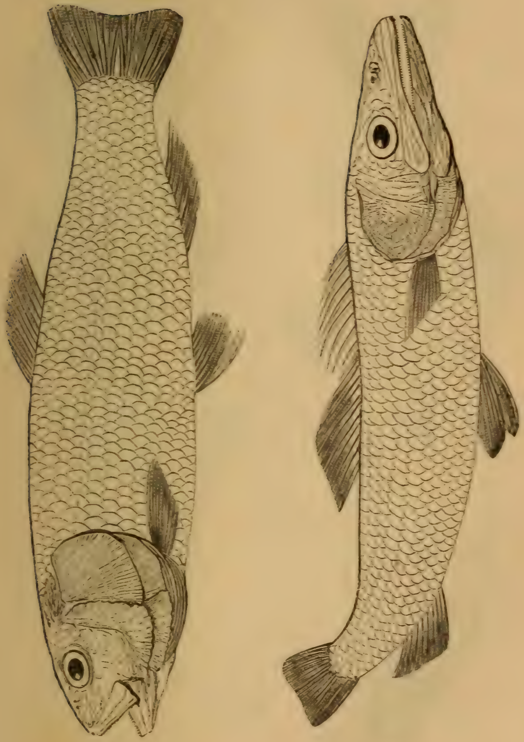
Certain fossil fishes closely allied to the *Perch*, were my first treasures of this class, and are among the most abundant of the Sussex ichthyolites. They belong to the genus *Beryx*, of which there are two species now living in the seas of Australia. Outlines of two of the most common species of the Sussex and Kentish chalk, are given in *Ligns.* 75 and 76. The horny capsule of the globe of the eye is often preserved in these fossils.†

The annexed figures (*Ligns.* 72, 73, 74, 75, 76) are restored outlines of seven of the Sussex ichthyolites, executed by Mr. Joseph Dinkel, the eminent artist employed by M. Agassiz.‡

* Consult Recherches sur les Poissons Fossiles, tome ii. part. 2de. p. 174.

† Medals of Creation, vol. ii. p. 659.

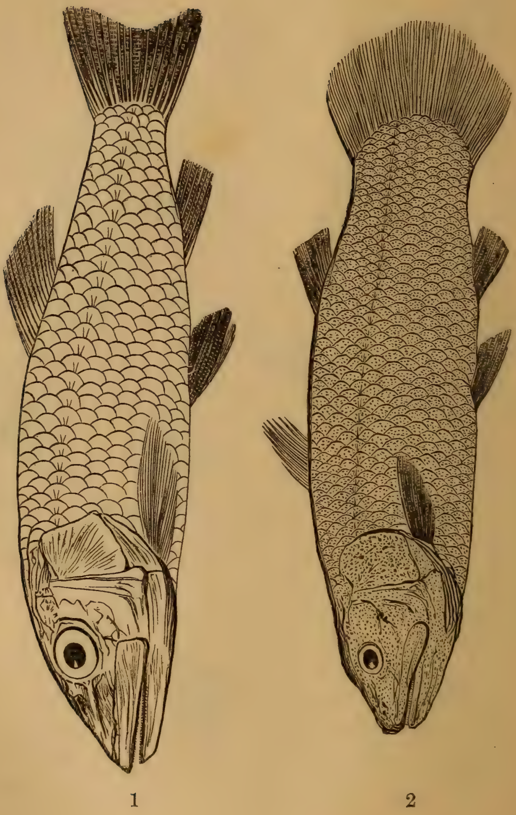
‡ Mr. Dinkel now resides in London; at 13, Great James-street, Bedford-row.



1 2

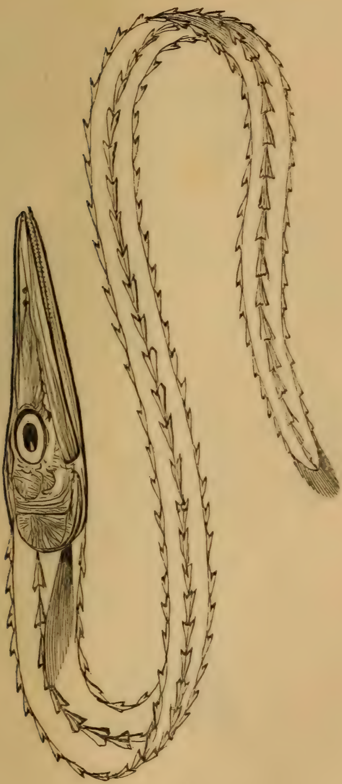
LIGN. 72.—Fig. 1. OSMEROIDES MANTELLI. Length 12 inches. From Lewes chalk-pits.

Fig. 2. ACROGNATHUS BOOPS. Natural size. *Unique.* From Lewes.



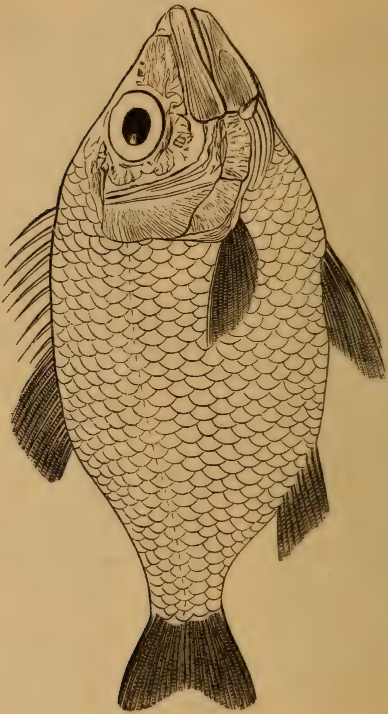
LIGN. 73.—Fig. 1. AULOLEPIS TYPUS. Length 6 inches. *Unique.* From Clayton chalk-pit.

Fig. 2. MACROPOMA MANTELLI. Length 24 inches. From the chalk quarries near Lewes.



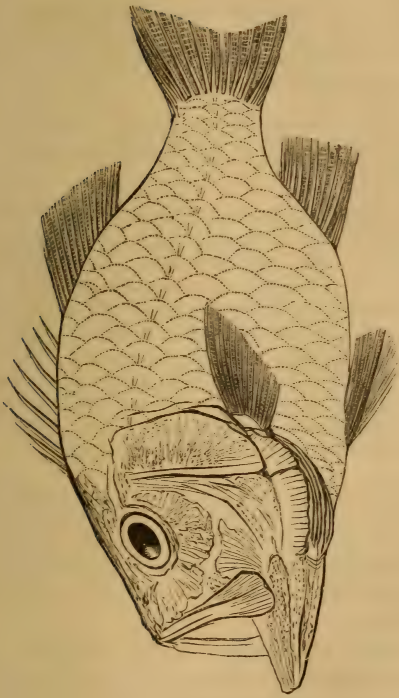
Lign. 74.—Dercetis elongatus. Length 16 inches. From Lewes.

Fragments of the cylindrical body of fishes of this genus occur abundantly in the chalk at Preston, near Brighton. The outline represents a specimen collected from the chalk near Lewes; it is the only instance in which the cranium remains.



LIGN. 75.—BERYX RADIANS. Length 7 inches. From the chalk-marl, near Lewes.

This species is generally found in the lower chalk and chalk-marl: specimens have been collected at Lewes, Clayton, Steyning, and Arundel, in Sussex; and at Burham, and near Maidstone, in Kent.



LIGN. 76.—BERYX LEWESIENSIS. Length 12 inches. From the Lewes Chalk.

This is the most abundant of the Sussex ichthyolites; and is called *Johnny Dory* by the quarrymen. Detached scales are very frequent in the chalk of the South Downs, and also in that of Kent and Surrey. Some fine specimens of this species have recently been found in the chalk of Chatham and Maidstone.

Lign. 72, *fig.* 1. *Osmeroides Mantelli.* This figure conveys a correct idea of the general outline of the fossil Salmons, found in the Lewes chalk.

Lign. 72, *fig.* 2. *Acrognathus boops.* I have seen but one specimen of this small fish; the relatively large jaw and eye are indicated by the name. The upward bend of the caudal extremity is doubtless accidental.

Lign. 73, *fig.* 1. *Aulolepis typus.* This is likewise an unique specimen of a fish six inches long, having scales of a peculiar character.

Lign. 74. *Dercetis elongatus.* Fragments of the elongated subcylindrical body of this fish very frequently occur in the chalk of Sussex, Kent, and Hampshire. Examples, two feet and even more in length, are occasionally met with; and yet but two instances are known, in which any vestiges of the skull, or of the tail, can be traced. In the specimen from which the figure was taken, the parts represented were clearly defined.* The Dercetis had on the sides three rows of dermal scutcheons (like those of the Sturgeon), that extended over the body, and the intervals between them were covered with small scales; in most specimens the latter only remain.

Lign. 75. *Beryx radians.* *Lign.* 76. *Beryx Lewesiensis.* Several examples of these ancient fishes of the Perch tribe have been found as perfect as in these delineations. Another and more delicate species, with a very small head (*Beryx microcephalus*), is occasionally obtained from the chalk-marl, exquisitely preserved.

In the other subdivisions of the cretaceous formation, remains of fishes occur more or less abundantly in various parts of England, the Continent, and America. One locality only can here be mentioned; Glaris in Switzerland has long been celebrated for the profusion and variety of its ichthyolites, which occur in a very hard, black, laminated shale. This shale is highly bituminous, and can scarcely be distinguished lithologically from some of the most

* See Medals of Creation, vol. ii. p. 658.

ancient slate rocks. But from the characters of the fossil fishes, which are all of cretaceous genera, M. Agassiz was enabled to solve the problem, and prove that the Glaris slates belong to the chalk formation ; the altered condition of the rock having resulted from the effect of high temperature under great pressure.

In concluding this cursory notice of the fishes of the cretaceous epoch I would remark that two-thirds of the genera, and almost all the species, are extinct, but related to tertiary forms. This result is in accordance with that derived from the examination of the zoophytes, mollusca, and other organisms, which have come under our notice in the course of this review.

38. Reptiles of the chalk.—The remains of reptiles discovered in this formation, though not very numerous, are sufficient to arrest attention, when contrasted with the entire absence of all traces of warm-blooded animals. We perceive, as it were, the first indications of that remarkable discrepancy in the relative numerical proportion of the mammalia and the reptilia, which distinguishes the secondary from the tertiary and modern epochs.

The most extraordinary of the reptiles peculiar to the chalk, is the Mosasaurus of Maestricht (*ante*, p. 311). A few vertebræ, apparently of this animal, have been found in the white chalk near Lewes. In the cretaceous strata of America, my friend Dr. George Morton, of Philadelphia, discovered teeth, which are specifically identical with the Maestricht reptile.* In the Essex chalk, portions of a jaw, with teeth, belonging to a saurian of the same genus, were discovered by Mr. Edward Charlesworth many years since ; the symmetrical form, and smooth surface of the teeth, separate them from the above, and Mr. Charlesworth has named the species *Mosasaurus stenodon.*

* Dr. Morton's Synopsis of the Cretaceous Strata of N. America, Pl. XI. *fig.* 9.

Teeth of crocodiles are mentioned by Baron Cuvier as having been obtained from the chalk at Meudon.

A considerable portion of a spinal column composed of concavo-convex vertebræ, with many ribs, and part of the pelvis, of a small lizard, were found in the chalk near Maidstone ; and another specimen of the anterior portion of the spine, with part of the cranium, has since been obtained by Mrs. Smith, of Tunbridge Wells. A jaw, with numerous subulate teeth, anchylosed by their base to an alveolar parapet of bone, as in the recent Iguana, has been discovered in chalk near Cambridge. These relics are referred by Prof. Owen to the same species of reptile, which he has named ***Raphiosaurus***.*

Remains of two genera of marine reptiles, the Ichthyosaurus and Plesiosaurus, occur, though rarely, in the white chalk of Sussex, Kent, and Dorsetshire.†

From the greensand of Kent one of the most interesting specimens of the Iguanodon has been obtained ; and in the same strata at Hythe, have been found numerous bones of a gigantic marine reptile, to which are also ascribed certain large conical striated teeth, that occur in the greensand of various localities.‡

That the *Pterodactyles*, those marvellous flying reptiles, existed during the cretaceous epoch, we have proof in several specimens of bones of the extremities, and of part of the cranium, and jaws with teeth, obtained from the chalk pit at Burham, in which the fossil turtle, presently to be noticed, was discovered.§

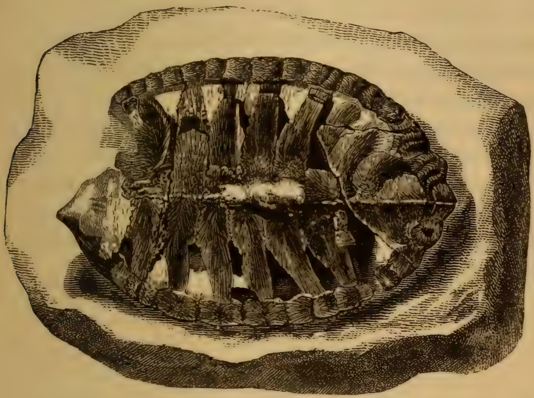
* Geol. Trans. vol. vi. Pl. 39 ; Medals of Creation, vol. ii. p 758.

† I have received a vertebræ of a Plesiosaurus from the chalk near Blandford, through the kindness of J. Shipp, Esq.

‡ Hence the name *Polyptychodon* has been given to this reptile. Medals of Creation, vol. ii. p. 728.

§ Figures and descriptions of this chalk Pterodactyle are given by Mr. Bowerbank in the Geological Journal for 1846.

39. Fossil Turtles.—Of the Chelonian reptiles or Turtles, remains of marine species are found abundantly in the limestone of St. Peter's Mountain, and in the slate of Glaris. In the white chalk of England relics of this kind are rare; but a few beautiful specimens of a small and very peculiar Turtle have been found in the chalk of Kent.* This reptile, which I have named in honour of its discoverer,



Lign. 77.—Fossil Turtle; from the chalk.

(Chelonia Benstedi; one-third the natural size.)

Chelonia Benstedi, appears to blend the characters of the Chelonians or marine turtles, with those of the *Emydes* or freshwater forms; and since my description of the fossil, figured in *Lign.* 77, another specimen has been found, which is of the same size, and presents similar characters to the one in my possession.† The upper part of the carapace

* At Burham, between Chatham and Maidstone.

† See my notice of a fossil Turtle from the chalk, Philos. Trans May, 1841; with two plates.

delineated in the drawing, *Lign.* 77, can be removed, so as to expose the bones of the plastron, or sternal plates, beneath. This fossil is six inches in length, and three and a half in breadth.

40. SUMMARY.—The characters of the Cretaceous Formation, as shown by these investigations, are those of a vast oceanic basin, filled up with organic and inorganic debris, and innumerable remains of the successive generations of marine animals which lived and died in its waters, through periods of incalculable duration.

The fossil fuci indicate that the chalk ocean possessed the usual marine flora; while the drifted masses of wood bored by teredines, and the fir-cones, stems of cycadeous plants, leaves of ferns, and bones of terrestrial reptiles, prove that its shores were bounded by dry land, which was clothed with forests, and inhabited by colossal oviparous quadrupeds. Of the higher orders of animals no unquestionable relics have yet been discovered.

A TABULAR ARRANGEMENT OF THE FOSSIL FISHES OF THE CHALK OF THE SOUTH-EAST OF ENGLAND, IN THE MANTELLIAN MUSEUM AT BRIGHTON.*

(*From "Recherches sur les Poissons Fossiles," by M. Agassiz.*)

"Tout le monde sait que le Musée de M. le Dr. Mantell à Brighton est une collection classique pour la craie, et la formation Veldienne. Les soins minutieux que M. Mantell a donnés depuis bien des années à ces fossiles, les ont rendus plus parfaits que tous ceux des autres musées : car souvent il est parvenu à les detacher entièrement de la roche dans laquelle ils se trouvaient ; ou du moins à les produire en relief, en détachant toutes les matières solides qui recouvraient les parties les mieux conservées de l'animal."

ORDER I.—The *Placoidians*, (from πλαξ, a broad plate.) The skin, covered irregularly with enamelled plates, sometimes of a large size, but frequently in the form of small points, as in the shagreen on the skin of sharks, and the tubercles on the integuments of rays.

---

* Now in the British Museum.

PTYCHODUS *latissimus*. Mantell's South Down Fossils. Tab. xxxii. fig. 19. Agassiz Poiss. Foss. Vol. iii. tab. 25.
——— *polygyrus*. Ibid. Tab. xxxii. figs. 23, 24.
——— *mammillaris*. Ibid. Tab. xxxii. figs. 18, 20, 25, 29.
——— *decurrens*.
——— *altior*. South Down Fossils. Tab. xxxii. figs. 17, 21, 27.

Teeth, and perhaps vertebræ, of the above species, and a few examples of their dorsal defences, (*Ichthyodorulites* of Dr. Buckland,) are the only remains hitherto discovered. (*Agass. Poiss. Foss.* Vol. iii. tab. 10[a], 10[b].) The teeth were referred to fishes of the genus Diodon, by previous authors, and the defences were called radii, or fin-bones of balistes, and siluri.

Teeth of a new species of *Ptychodus* (*P. Mortoni*) have been discovered in the sand of New Jersey, United States, by Dr. Morton.—(*Morton's Synopsis,* Pl. 18, figs. 1, 2.)

PTYCHODUS,—*spec. undetermined*. Dorsal defences, and a beautiful example of a fin, are represented in the Fossils of the South Downs. Tab. xxxiv. fig. 8. Tab. xxxix. and Tab. xl. fig. 3.
GALEUS *pristodontus*. South Down Fossils. Tab. xxxii. figs. 12 to 16. Agass. Poiss. Foss. Vol. iii. tab. xxvi. fig. 14.
NOTIDANUS *microdon*. Agass. Tab. xxxii. fig. 22.
LAMNA *appendiculata*. Agass. Tab. xxxii. figs. 2, 3, 5, 6, 9.
——— *acuminata*. Agass. Tab. xxxii. fig. 1.
——— *Mantelli*. Agass. Tab. xxxii. figs. 4, 7, 8, 10.
——— *crassissima*.
ODONTAPSIS *raphiodon*.
SPINAX *major*. Agass. Poiss. Foss. Vol. iii. tab. 10, figs. 8, 14.
PSAMMODUS *asper*. Poiss. Foss. Vol. iii. tab. 10, figs. 1, 3.
ACRODUS *transversus*. Poiss. Foss. Vol. iii. tab. 10, figs. 4, 5.
GYRODUS *angustus*. Poiss. Foss. Vol. ii. tab. 66a, figs. 14, 15.

The above order of fishes is represented by five genera, of which one, containing twelve species, is extinct. The fishes of the genera Ptychodus, Galeus, and Lamna, are very widely distributed.

ORDER II.—The *Ganoidians*, (γανος, splendour, from the brilliant surface of their enamel.) These are characterized by angular scales, formed of horny or bony plates, protected by a thick layer of enamel, *Lign.* 68, *fig.* 1, p. 339.

MACROPOMA *Mantelli*. South Down Fossils. Tab. xxxvii. and xxxviii. Agass. Poiss. Foss. Vol. v. tab. 60b, fig. 2.
——— Coprolites of: South Down Fossils. Tab. ix. figs. 5, 11. Agass. Poiss. Foss. Vol. ii. tab. 65.

The Macropoma is perhaps the most remarkable of all the chalk fishes; in most examples the membranes of the stomach are preserved.

SPHŒRODUS *mammillaris.* From Clayton chalk-pit.
DERCETIS *elongatus.* Lign. 74, page 349. Length 16 inches. South Down Fossils. Tab. xxxiv. figs. 10, 11. Tab. xl. fig. 2. Agass. Poiss. Foss. Vol. ii. tab. 66a, figs. 1 to 8.

The above order comprehends three extinct genera, with three species. Another species of *Dercetis* has been found in the chalk of Westphalia.

ORDER III.—The *Ctenoïdians,* (κτεις, a comb.) The scales of this order are pectinated on their posterior margin, like the teeth of a comb, and are composed of laminæ of horn or bone, but have no enamel. *Lign.* 68, *fig.* 4, p. 339.

BERYX *Lewesiensis.* (B. ornatus of Agassiz.) South Down Fossils. Tab. xxxiv. fig. 6. Tab. xxxv. Tab. xxxvi. Agass. Poiss. Foss. Vol. iv. tab. 14a.
——— *radians.* History of the County of Sussex. Vol. ii. Part ii. p. 15, fig. 22. Agass. Poiss. Foss. Vol. iv. tab. 14b, fig. 7.
——— *microcephalus.* Agass. Poiss. Foss. Vol. iv. tab. 4c, figs. 7 to 9.

There are other species of Beryx in the chalk of Bohemia and Westphalia; and genera nearly related to *Beryx,* in the schist of Glaris.

ORDER IV.—The *Cycloïdians,* (κυκλος, a circle) The scales smooth, with a simple margin, composed of laminæ of horn or bone without enamel. *Lign.* 68, *fig.* 3, p. 339.

OSMEROIDES *Mantelli.* (*Salmo Lewesiensis* of Mantell.) South Down Fossils. Tab. xxx. fig. 12. Tab. xxxiv. fig. 3. Tab. xl. fig. 1. Agass. Poiss. Foss. Vol. v. tab. 60o.

To the above species belong the remarkable uncompressed specimens now in the British Museum.

OSMEROIDES *Lewesiensis.* Agass. Poiss. Foss. Vol. v. tab. 60c. (*Salmo? Lewesiensis* of Mantell.) This species is more elongated than *O. Mantelli,* and the number of rays in the dorsal fin is greater.
———— *granulatus.* History of Lewes. Vol. i. plate xxix. fig. 13. The bones of the head, with the jaws and teeth, have alone been discovered. Agass. Poiss. Foss. Vol. v.
ENCHODUS *halocyon.* South Down Fossils. Tab. xxxiii. figs. 2, 3, 4. Tab. xliv. figs. 1, 2. Agass. Poiss. Foss. Vol. v. tab. 25, figs. 11 to 6.
SAUROCEPHALUS *lanciformis.* (Harlan.) South Down Fossils. Tab. xxxiii. figs. 7, 6. Trans. Geol. Soc. of Pennsylvania, Vol. i. p. 83. Agass. Poiss. Foss. Vol. v. tab. 25, figs. 21 to 29.
SAURODON *Leanus.* (Hays.) Trans. American Philos. Society, vol. for 1830, plate 16. Agass. Poiss. Foss. Vol. v. tab. 25, figs. 17 to 20.
HYPSODON *Lewesiensis.* South Down Fossils. Tab. xxxiii. fig. 8. Tab. xlii. figs. 1 to 5. Agass. Poiss. Foss. Vol. v. tab. 25a.

From the resemblance of the teeth of this fish to those of reptiles, it was supposed that the original belonged to an extinct genus of saurians; but in 1833, a considerable portion of the head, with the maxillæ, many vertebræ, &c., were discovered in a block of chalk, near Lewes, and the true characters of this remarkable ichthyolite determined.

The statement that the teeth of the Saurodon and Saurocephalus were first ascertained to belong to fishes, and not to reptiles, by the microscopical observations of Prof. Owen, is not correct, for M. Agassiz had long previously determined their true characters.

*** The following fishes have been named by M. Agassiz, since the above table was constructed.

ACROGNATHUS *boops*. Lign. 72, page 347. Natural size. Agass. Poiss. Foss. Vol. iii. tab. 60a, figs. 1, 4. An unique specimen from Southerham quarry, near Lewes.

AULOLEPIS *typus*. Lign. 73, page 348. Length 6 inches. An unique specimen, from Clayton chalk-pit, Sussex. One nearly perfect example has alone been found. Poiss. Foss. Vol. iii. tab. 60, figs. 5, 8.

BELONOSTOMUS *cinctus*. Agass. Poiss. Foss. Vol. ii. tab. 66a, figs. 10 to 13.

CHIMERA *Agassizii*. Agass. Poiss. Foss. Vol. iii. pl. 40, figs. 3, 5. (Determined by Dr. Buckland.) The beaks or mandibles have alone been discovered.

———— *Mantelli*. Lign. 71, page 343. Agass. Poiss. Foss. Vol. iii. Pl. 40, figs. 1, 2. Two mandibles were found, many years since, in a block of chalk, near Lewes. This species also occurs in the Shanklin sand of Kent. A beak has been found by Mr. W. H. Bensted, in the Iguanodon quarry, near Maidstone.

TETRAPTERUS *minor*. Lewes. Agass. Poiss. Foss. Vol. iii. tab. 60, figs. i. 4.

CATURUS *similis*. Agass. Poiss. Foss. Vol. ii. tab. 66a, fig. 9.

ACROTEMNUS *faba*. Poiss. Foss. Vol. ii. tab. 66a, figs. 16, 18.

LECTURE IV.

PART II.

1. GEOLOGY OF THE SOUTH-EAST OF ENGLAND.—From this survey of the marine formation of the Chalk, we turn to the remarkable fluviatile deposits, of which the basin of the cretaceous ocean, in the south-east of England, was composed; in other countries, as I shall hereafter have occasion to remark, that ocean-bed was formed of the Oolite and other more ancient rocks. It will now be necessary to offer a few observations on the geology of the district in which the Wealden is so largely developed.

The strata of the south-east of England belong to three principal groups or formations. The *first* consists of the *Tertiary* sands, clays, and gravel, described in the previous Lecture, which occupy depressions in the chalk.

The *second* is the *Chalk*, (including under this term the White-chalk, Galt, and Greensand,) which forms the most striking feature in the physical geography of the country. The upper division of this formation constitutes the South Downs, which, from the bold promontory of Beachy-head, traverse the county of Sussex from east to west, and pass through Hampshire into Surrey; from Godalming the chalk hills extend by Godstone into Kent, where they are called the *North Downs*, and terminate in the line of cliffs that stretches from Dover to Ramsgate. The lowest member of the chalk, the *Greensand*, appears as a chain of hills of irregular elevation, skirting the escarpments of the chalk downs; the *Galt* occupying the intermediate valley.

The *third* group fills up the area between the North and South Downs; the most elevated masses form the *Forest-ridge*, which traverses the district in a direction nearly east and west, and is composed of alternations of sandstones, sands, shales, and clays, with a deep valley on each flank, called the *Weald:* hence the geological designation of the whole series. From the central ridge of the Wealden, which varies in height from 400 to 800 feet, and stretches from Fairlight Down near Hastings on the east, to beyond Horsham on the west, the strata diverge on each side towards the Downs, constituting an *anticlinal axis*, and finally disappear beneath the lowermost beds of greensand. There are conclusive proofs that the Wealden strata were originally covered by the chalk, and that their present position and appearance are attributable to changes which have taken place subsequently to the cretaceous epoch.*

* See Geology of the South-East of England, chap. xi.

2. GEOLOGICAL PHENOMENA BETWEEN LONDON AND BRIGHTON.—The direct turnpike roads from London to Brighton pass over the whole series of these deposits, as well as those described in the previous lectures. Proceeding from the Thames, the observer successively traverses the modern silt of the river—the ancient drift and alluvium, containing remains of elephants and other large mammalia—and if he proceeds by Reigate, his road, through Clapham and Tooting, lies over beds of clay and gravel, which are part of the ancient shores of the London basin. At Sutton he ascends the chalk hills of Surrey, and travels along an undulated tract of country, formed by the elevated masses of the ancient cretaceous ocean-bed just described. Arriving at the precipitous southern escarpment of the North Downs, a magnificent landscape, displaying the physical geography of the Weald, and its varied and picturesque scenery, suddenly bursts upon his view. At his feet lies the deep valley of Galt in which Reigate is situated, and immediately beyond the town, appears the elevated ridge of Greensand, which stretching towards the west, attains at Leith Hill an altitude of one thousand feet ;* and to the east forms a line of sand-hills, by Godstone and Sevenoaks, through Kent, to the sea-shore. The Forest-ridge of the Wealden occupies the middle region, extending westward towards Horsham, and eastward to Crowborough Hill, its greatest altitude, and thence to Hastings, having on each flank the wealds of Kent and Sussex ; while in the remote distance, the smooth and undulated summits of the South Downs appear like masses of grey clouds on the verge of the horizon.

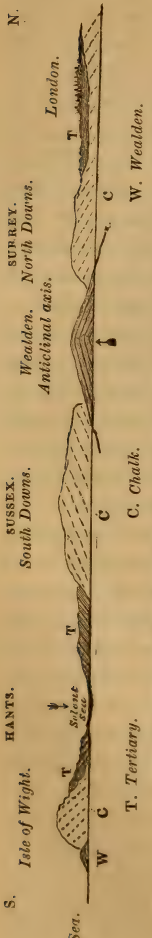
Pursuing his route, the traveller passes through Reigate, along the valley of *Galt*, and over the *Greensand* of Cockshut Hill, and arrives at the commencement of the *Wealden.*

* See my "*Memoir on the Geology of the Country seen from the summit of Leith Hill*," in Brayley's History of the County of Surrey, published by Mr. Ede, of Dorking.

The *Weald clay*, containing beds of fresh-water limestone, appears at Horley common ; and while in the commencement of his journey the roads were made of broken chalk-flints, and at Reigate of cherty-sandstone, the materials here chiefly employed are the bluish-grey calcareous rock of the Weald. At Crawley, sand and sandstone appear, and the road is constructed of grit and limestone, containing fluviatile shells, bones, and plants. Crossing *Tilgate Forest* and *Handcross*, over a succession of elevated ridges of sandstone, and through clay valleys, produced by the alternations of the strata, he descends from the sandstone ridge at Bolney, near Cuckfield, and again journeys along a district of Weald clay with fresh-water limestone. *Green-sand*, like that of Reigate, reappears at Hickstead, and is succeeded by a tract of *Galt;* and finally, entering a valley of Chalk-marl, he reaches a defile in the South Downs, through which the road winds its way to Brighton ; the traveller having in the course of his journey passed from one chalk range to the other, and crossed over the intervening area formed by the delta of the Wealden.

3. London and Brighton railway section.—A similar section is displayed along the line of railway from London to Brighton. Leaving the station at London-bridge, the tertiary clays with their characteristic fossils, are seen from beyond Deptford, by New Cross, Sydenham, &c. ; and approaching Croydon, beds of gravel appear, with interspersions of olive-green sand. The valley beyond Croydon, along the side of which the railway proceeds, is a thick bed of gravel resting on the chalk. Beyond the station called *Stoats'-nest*, is a fine section of the chalk with flint, and the North Downs are traversed by a long tunnel carried through the solid chalk, and emerging near Merstham, where the firestone and marl rise to the surface. The sands and clays of the chalk are passed at the Red Hill, and Godstone stations, and the Wealden clays appear at Horley, and

are succeeded by shales, limestones, sands, and sandstones, to the Crawley station.



LIGN. 78.—SECTION FROM LONDON TO THE SOUTHERN COAST OF THE ISLE OF WIGHT.

Passing through a long tunnel in the Wealden, we arrive at Balcombe, where laminated sandstone and shale are seen on each side the cutting. The general dip of the strata hitherto passed is to the *north-east;* but after crossing the deep wealden valley beyond Balcombe, over a magnificent viaduct, the line runs along alternating layers of sands and clays, which dip to the *south-west;* we have therefore arrived on the southern side of the grand anticlinal axis of the Forest ridge. The wealden strata continue, with the same general inclination, by Hayward's Heath, which is traversed by a tunnel, to beyond St. John's Common, where they disappear beneath the lowermost greensand beds of the chalk formation. The galt, firestone, and marl succeed, and, lastly, the white chalk of the South Downs, at Clayton Hill; through the base of which a long tunnel passes, and emerges on the south of the Downs. The remainder of the line to the Brighton station, runs over, or through, hills and valleys, of the white chalk. Thus this railway passes through two ranges of chalk hills, *viz.* the North and South Downs, by tunnels; two of greensand, *viz.* near Red Hill in Surrey, and Hurstperpoint in Sussex; and two principal ridges of wealden, *viz.* at Balcombe, and Hayward's Heath. If we take a line bearing more to the west; as, for example, from London to the southern shores of the Isle of Wight, in Sandown Bay, we shall have the section represented in *Lign.* 78, which exhibits the entire series of the deposits, and their relative position in the south-east of England.

The older tertiary or eocene strata, forming the site of London, are seen occupying a depression of the chalk ; the North Downs of Surrey next appear—then the anticlinal ridge of the Wealden—the South Downs of Sussex and Hampshire succeed—covered on the south by the marine tertiary strata of Southampton—then the depression in the strata occupied by the Solent—the north of the Isle of Wight covered by fresh-water and marine eocene deposits—next the vertical chalk range of the Island—and, lastly, the emergence of wealden beds from under the greensand, in Sandown Bay.*

4. THE WEALDEN.—The tertiary basin of London afforded an example of the accumulation of detritus and organic remains in an inland sea ;—that of Paris, of marine and fresh-water sediments, deposited in a gulf open to the sea on the one side, and fed by rivers and thermal springs on the other ;—the lacustrine formations of Auvergne, of the gradual precipitation of strata in the tranquil waters of lakes ;—the cretaceous formation, of the operations which have taken place in the profound abyss of an ocean ;—while the series of deposits to which the term *Wealden* is applied, presents the most striking instance of an ancient delta hitherto discovered. Yet strange as it may appear, although these strata occupy the whole area between the North and South Downs—a tract of country traversed daily by hundreds of intelligent persons from the metropolis—their peculiar characters were entirely unknown twenty-five years ago ; the whole group being then sup-

* See Geology of the Isle of Wight, p. 74.

posed by geologists to belong to a series of marine clays and sands below the chalk.*

Before entering upon the description of these strata, I would remind you of the effects of rivers, and the nature

* See Conybeare and Phillips's Outlines of the Geology of England and Wales, pp. 140, 155.

Although the shells forming the Sussex marble of the Wealden, were supposed, so long since as Woodward's time, to be fluviatile species, yet this point was controverted by many able conchologists; and few if any other organic remains, had then been obtained from the strata of the weald. Having for several years diligently collected the fossils of the chalk, galt, firestone, &c. in the south-east of Sussex, and around my native South Downs, I was struck with the want of accordance between them and some specimens of shells, bones, and plants, I had procured from the quarries, wells, and cuttings made in the Wealden district; and by degrees, the fluviatile origin of the deposits forming the area between the greensands of Sussex, Kent, and Surrey, became manifest. The absence of *ammonites, echinites, terebratulæ, corals,* and other common and characteristic fossils of the chalk, in my Wealden collection, was a circumstance that especially arrested my attention: and the discovery of bones of large terrestrial reptiles, with trunks and foliage of land plants, and of innumerable river shells and crustaceans, in the strata of Tilgate Forest—of which there were not the slightest traces in the cretaceous deposits,—corroborated the inferences suggested by my previous observations. In 1822, the Tilgate strata and their peculiar fossils were first described, and the fluviatile origin of the deposits pointed out, in my Fossils of the South Downs; chap. vi. p. 37. In June of the same year, I communicated to the Geological Society of London, an account of the extension of these strata over the weald, being the result of my own and Mr. Lyell's observations. In 1827, my Fossils of Tilgate Forest appeared, containing nearly 200 figures of Wealden Fossils. As the discovery of the fluviatile character of these deposits has recently been attributed to other observers, I feel myself called upon to state thus briefly the history of my humble labours; and to corroborate it by the following quotations from Professor John Phillips and Dr. Fitton.

"Until the appearance of Dr. Mantell's works on the Geology of Sussex, the peculiar relations of the sandstones and clays of the interior of Kent, Sussex, and Hampshire, were entirely misunderstood. No one supposed that these immense strata were altogether of a of modern fluviatile deposits, as explained in a previous Lecture (p. 56). We found the deltas of rivers to consist of clay (or indurated mud), alternating with beds of sand and sandstone (or consolidated sand), and containing leaves, branches, and trunks of trees, fresh-water shells, works of art, bones of man, and of land animals, more or less rolled, —with boulders formed of fragments of rocks, transported by torrents from the hills, or washed out of the banks by the streams.

Let us now suppose that by agencies already explained, a river has disappeared, that the sea also has changed its place, and that the bed of the river and the delta, have become dry land ; that towns and villages have been built upon the consolidated fluviatile sediments, and that the surface is either clothed with turf or forests, or under cultivation. If sections of the strata were exposed, either by natural or artificial means, and the bones of men and animals, with works of art, and remains of plants and shells, were visible in the clay or sandstone, such appearances would excite in us no surprise, because we have made ourselves acquainted with the process by which such deposits are accumulated. And should an inhabitant of the new country express his wonder how brittle shells, and delicate leaves, and bones, had become imbedded in the solid rock ;

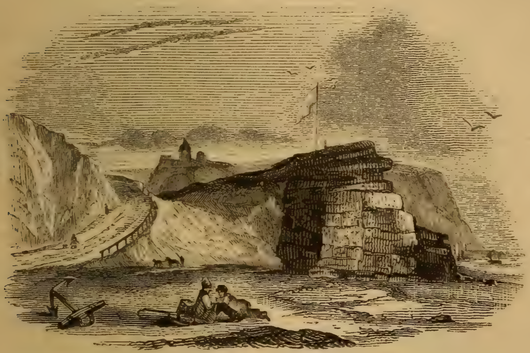
peculiar type, and interpolated amid the rest of the marine formations, as a local fresh-water deposit, of which only very faint traces can be perceived in other parts of England."—*Professor John Phillips, Ency. Metropolitana,* p. 631. Art. *Geology.*

" It was not until the appearance of Dr. Mantell's Illustrations of the Geology of Sussex, in 1822, that the full value of the evidence which this district affords was made to appear. In that valuable work the author clearly showed, that the extraordinary remains which he had discovered in the beds of Tilgate Forest, must have originated in a lake or estuary, and have been the produce of a climate much warmer than that which is now enjoyed in England."—*Dr. Fitton's Geology of Hastings,* p. 14.

and if when we stated the manner in which those changes had been effected, he should not only refuse his assent to our explanation, but insist that the shells, leaves, and bones, were merely accidental forms of the stone, should we not feel astonished at his ignorance and prejudice?—yet not a century since, and such an opinion almost universally prevailed, and is even still entertained by many. And farther, if our assumed personage admitted that the remains in question were fossil animals and vegetables, but asserted that they had been entombed in the strata by a general deluge which had softened the crust of the earth, and engulfed in the sediments of its waters the remains of animated nature—should we not reply, that as such a catastrophe must inevitably have mingled together the relics of animals and vegetables, whether of the land, the rivers, or the seas—the regular stratification of the materials composing the delta, and the exclusive occurrence of land and fresh-water productions, were fatal to such a supposition, and afforded conclusive evidence of the correctness of our explanation of the phenomena?—it was by such inductions that the fluviatile nature of the Wealden was established.

5. WEALDEN OF THE SUSSEX COAST.—From the distribution of the Wealden over the south-east of England, instructive sections have been formed between Beachy Head and Dover, by the action of the sea along the coast. From the stupendous cliffs of Beachy Head, the Chalk extends towards Southbourn, where beds of Galt, Firestone, and Greensand, successively emerge, forming the base of the shore, and abounding in characteristic marine fossils. Passing over Pevensey Levels, the boundary of which on the sea-side is obscured by modern shingle, we arrive at Bexhill and Bulverhithe, and find the cliffs composed of laminated sandstones and clays; and those of St. Leonard, of similar strata, more extensively developed: sands and clays separated into very thin laminæ, alternate with

conglomerates, indurated sand-rock, and a fine sandstone, of great compactness, called *grit*. At Hastings, sands and clays, with interspersions of lignite, laminated shales, grits, and sandstones, constitute a long range of high cliffs.* The general resemblance of these strata to fluviatile sediments is most striking; the laminated structure of the clays and shales, the constant intermixture of minute portions of lignite, the absence of pebbles and shingle, and the alternations of mud and sand, are lithological characters constantly observable in river deposits.



LIGN. 79.—WHITE ROCK, HASTINGS; FROM THE SOUTH-WEST.

(*Drawn by Miss Jane Allnutt.*)

a, Inland cliff of laminated sandstone and clay; *b*, Cliff to the east of Hastings. The White rock is marked by the flag on its summit; it is composed of calciferous grit.

To the west of Hastings a fine mass of the strata, comprising several layers of calciferous grit, alternating with

* See A Guide to the Geology of Hastings; by W. H. Fitton, Esq. M.D. F.R.S. &c. My Geology of the South-East of England, contains a map, sections, and details of the geological structure, of this interesting district.

friable sandstone, was formerly exposed on the sea-shore; having at a very remote period been separated from the adjacent cliff. The action of the waves having bleached the projecting layers of grit, the mass obtained the local name of "*White roek*" (*Lign.* 79); but the late improvements at St. Leonard's have removed all traces of this outlying portion of the Hastings beds.* The nature of the organic remains which the strata contain will be considered hereafter.

6. Pounceford.—In the interior of the country, the quarries opened along the ridges formed by the compact grit, afford various instructive sections; and the valleys which are eroded by streams, expose in many places the beds of shales, laminated clays, and limestones. Pounceford, on the estate of the Earl of Ashburnham, on the road to Burwash, in Sussex, presents several highly interesting sections of these deposits. Descending through a defile cut through the Hastings sands, we arrive at the bottom of a deep glen, along which a rapid stream, that bursts out from between the clay-partings, rushes to a distant and lower valley. On each side the vale, openings are made to arrive at a greyish blue limestone abounding in shells, which is employed on the roads, and is also converted into lime for agricultural purposes. Where the stone lies deep, shafts are sunk from the surface, and after the extraction of the limestone, they are deserted and filled up. This spot is highly interesting and picturesque; incrusting springs issue from the limestone beds, and deposit tufa on the mosses, equiseta, and land-shells. Thousands of fossil shells are seen in the clays and shales; and stems of plants, scales of fishes, teeth and bones of reptiles, and other remains, are imbedded in the stone; while the banks where newly exposed, exhibit numberless alternations of

* Geology of the South-East of England, p. 194.

laminated shales and clays, full of fresh-water shells.* In a visit to this place with my friend Mr. Lyell, in 1831, many new species of shells were found in the bed of the stream, having been washed out of the banks of clay ; and we collected teeth of crocodiles, and bones of fresh-water turtles, and of other reptiles. Several species of *Cyclas*, and of *Potamides*, were abundant in the clay (*Lign.* 97) ; and a mussel shell, which I named *Mytilus Lyellii*, to commemorate our excursion (*Lign.* 98, *fig.* 2), also a fluviatile species, was found in a mass of shale that had fallen into the rivulet.

7. Tilgate Forest.—As the *grit*, or calciferous sandstone, forms an excellent road-material, the quarries along the principal lines leading from the metropolis to the south-eastern coast, are very numerous ; and those spread over the area of Tilgate and St. Leonard's Forests, were extensively worked some twenty-five years since, when an increased communication between London and Brighton, rendered it alike necessary and profitable, to keep the turnpike roads in the best possible state.

This district may be described as bounded on the west by the London roads leading through Horsham, and on the east by those which pass by Lindfield, and Cuckfield ; the Crawley road, as previously mentioned, passing through Tilgate Forest. These localities, particularly the latter, have acquired much celebrity for their organic remains; the quarries in that part of Sussex having been the principal source, whence the specimens figured in my work on the "*Fossils of Tilgate Forest*"† were derived ; but every quarry throughout the Forest-range, from Loxwood in Western Sussex, to Hastings, have yielded the peculiar fossils of the wealden, more or less abundantly.

* See Fossils of Tilgate Forest, p. 47. Geology of the South-East of England, p. 22.

† The Fossils of Tilgate Forest, 1 vol. 4to. with plates, 1827.

The quarries around Tilgate Forest, where the calciferous grit is worked, present the following section :—

1. *Uppermost.* Loam or clay—from one, to five or six feet in depth; destitute of fossils.
2. Sandstone of various shades of fawn, yellow, and ferruginous colour; in laminæ, or thin layers, occasionally containing organic remains and pebbles; eight feet thick.
3. *Calciferous grit,* or *Tilgate stone*—a very fine sandstone, formed of sand cemented together by calcareous spar; it occurs in large masses of a concretional form, imbedded in soft sandstone. This grit has evidently been formed by the percolation of water charged with calcareous matter into loose sand; it abounds in bones and teeth of reptiles; stems and leaves of plants; shells, &c.
4. Sandstone, with concretionary masses of grit; and conglomerate formed of rolled pebbles of sandstone, jasper, quartz, rock-crystal, indurated clay, bones and teeth of reptiles, and of fishes; rolled masses of the grit and sandstone are found in this conglomerate; the organic remains which it contains are generally much waterworn.
5. Blue clay and marl—depth unknown.

This is the usual series of strata exposed in the quarries around Cuckfield, Lindfield, Bolney, &c. Near Horsham the fawn-coloured sandstone is more compact, and of a slaty structure. The thin slabs are used for roofing, and the thicker ones for pavements ; their surfaces are sometimes deeply furrowed or rippled ; an appearance upon which I will here offer a few observations.

8. Ripple-marks on sandstone.—The furrowed surface of the sandstones and grits which are used for paving in Horsham, Crawley, and other towns and villages on the Forest-ridge, must have attracted the attention of most persons who have travelled from Brighton to London. The appearance of these slabs, is similar to that presented by the sand along the sea-shore at low water, when the ripples occasioned by the receding waves have been deeply impressed ; the markings on the stone have arisen from a similar cause. In many instances the surface is so rough,

that the stone is employed in stable-yards, where an uneven floor is required, to prevent the feet of animals from slipping in passing over. It sometimes happens that when a large area of a quarry is cleared from the soil which covers it, a most interesting appearance is presented, the whole surface being rippled over like the strand on the sea-shore ; and the spectator is struck with the conviction, that he is standing on the sands of some ancient delta, or estuary, now turned into stone. Sometimes the furrows are deep, showing that the water was much agitated, and the ripple strong ; in other instances the undulations are gentle, and intersected by cross ripples, proving a change in the direction of the waves. Some slabs are covered by slightly elevated, longitudinal ridges of sand, made up of gentle risings, disposed in a crescent-like manner ; these have been produced by the rills which flowed back into the river, at low water. In other examples, the surface is marked by angular ridges irregularly crossing each other, like the fissures in septaria ; these have obviously been caused by deposition into crevices produced in sand or mud by desiccation. Many slabs of stone, the smooth, as well as the furrowed varieties, are covered with small, subcylindrical markings, which are the trails formed by vermes, or mollusca ; but I have searched in vain for the foot-marks of turtles or other reptiles, whose bones are so abundant in these strata. The frequent occurrence of impressions of the feet of animals on the rippled sandstone of other formations, renders it probable, that sooner or later, the tracks of some of the oviparous quadrupeds of the Wealden, will be discovered on the slabs of Tilgate stone. The deepest furrows have generally a slight coating of bluish clay, charged with minute portions of lignite, and other vegetable matter ; an appearance probably caused by the streams from the shore, that flowed over and coated the rippled sand. The phenomena here noticed afford an interesting example of the perfect similarity of a natural process, in periods separated from each other by immense intervals of time.*

9. SUBDIVISIONS AND EXTENT OF THE WEALDEN.—The Wealden is subdivided into several groups, which are characterized by the lithological nature of the strata, and the prevalence of certain kinds of fossils ; but throughout the whole, the fluviatile character of the formation is maintained : in the lowermost part of the series only are there any intrusions of a marine or estuary nature. In fact, it is not possible to conceive an accumulation of sedimentary detritus more purely fluviatile—a delta more free from marine exuviæ. Yet foreigners, and even some English geologists, describe it as a fluvio-marine formation ; "*un mêlange de fossiles marines et d'eau douce.*" †

Although it is not within the scope of these lectures to enter upon details of stratification, it is necessary to point out the principal subdivisions of this extensive system of fresh-water deposits.‡

1. WEALDEN UPPER CLAYS AND SANDS.—Stiff blue clays, with septaria, argillaceous ironstone, and beds of shelly limestone, called *Sussex or Petworth marble.*
2. TILGATE-GRIT AND HASTINGS-SANDS. — Fawn-coloured sand, and sandstones, with beds of calcareous grit or *Tilgate-stone,* alternating with blue clays and limestones, marls, and lignite.
3. ASHBURNHAM BEDS.—Alternations of clays, shales, and bluish-grey shelly limestones and shales.
4. PURBECK BEDS.—Clays, sandstones, and shelly limestone called *Purbeck marble.* Limestone, with layers of *vegetable mould,* and trunks of trees in a vertical position—the petrified *Forest of Portland.*

---

* For a particular account of the Wealden strata in the south-east of England, see my Geology of the South-East of England; Fossils of Tilgate Forest; and Geological Excursions round the Isle of Wight, p. 269.

† M. Pictet—Traité Elémentaire de Palæontologie.

‡ Geology of the South-East of England, p. 182.

Such is the assemblage of deposits to which the term Wealden, first employed in this acceptation by Mr. Martin,* is geologically applied. Alternating layers of clays, sands, and limestones, almost wholly composed of fresh-water univalves, and of small bivalves with minute crustaceans, form the upper series. Sand and sandstone, with bands of arenaceous limestones or calciferous grits, shells, and irregular interspersions of lignite, compose the middle group; while in the lowermost, sands, clays, and argillaceous shelly limestones, with small bivalves, again appear. Another series of clays and limestones, characterized by extensive beds of very small univalves, generally in the state of marble (*Purbeck marble*), succeeds; and buried beneath the whole, is a petrified pine-forest, with cycadeous plants; the trees still erect in the soil in which they grew! And in all these deposits, bones of colossal terrestrial reptiles are more or less abundant.

The upper clays and limestones occupy the valleys of the Wealden districts that skirt the inner escarpments of the chalk downs, in Surrey, Kent, and Sussex; the middle group of sands and sandstones, constitutes the Forest ridge of those counties; and the lower series appears in the deep valleys in the east of Sussex, around Battle, Brightling, Burwash, and Ashburnham.

The Purbeck strata, which are distinguished by thick beds of shelly limestone, principally formed of one small species of paludina, appear on the coast of Dorsetshire, in the Island, or more properly the peninsula, whose name they bear. The lowermost deposits of the Wealden, range along the southern shore of the Isle of Purbeck, and crest the northern brow of the Isle of Portland; overlying the oolitic limestones and clays, of which that insular mass of strata is chiefly composed.

* Geology of Western Sussex, by I. P. Martin, Esq.

The Wealden beds, or rather the lowermost division, the Purbeck, also occur in the vale of Wardour, which is a valley of denudation, in the south of Wiltshire, representing on a small scale that of the south-east of England. In this valley the various members of the chalk occur in their regular order of superposition, resting on clay and Purbeck limestone, and having the Portland stone beneath.*

At Stone in Buckinghamshire, and Swindon in Wiltshire, the oolite is capped by layers of freshwater limestone and marl of the Purbeck series.

In France, on the coast of the Lower Boulonnais, and in the valley of Bray near Beauvais, strata of a like character are observable, in which the Sussex marble (*lumachelle-à-paludines*), and a fern peculiar to the Wealden, have been discovered by M. Graves of Beauvais, to whom I am indebted for specimens. There can be no doubt that this formation originally extended over a much larger area ; for the same fossil fern (*Lonchopteris Mantelli*, *Lign.* 88) has been found in strata beneath the greensand, in Sweden, by Professor Nillson ; who informed me that several of the plants from Tilgate Forest, were analogous to specimens he had collected in the little island of Bornholm, off the Danish coast. Without implicitly relying upon the correctness of all these observations, the Wealden may be estimated as spreading over an area of more than 200 miles in length from west to east, and 220 miles from north-west to south-east ; an extent but little exceeding the delta of the Ganges or of the Mississippi, and surpassed by that of the Quorra, which forms a surface of 25,000 square miles, an area equal to half the superficial surface of England.† The total thickness of the Wealden deposits is estimated at 2000 feet, which is four times that of the delta of the Mississippi.

* Dr. Fitton, "*On the beds below the Chalk*;" Geological Transactions, 1837, p. 424.

† Dr. Fitton.

10. Wealden of the north of Germany.—In the north of Germany, the Wealden formation has been traced by M. Römer,* and other observers, over a considerable part of Hanover, covering a large area to the north of the Porta Westphalica, including the coal-field of Bückeburg ; the impure coal of which resembles our Sussex lignite.† These Wealden deposits lie upon the oolite, and beneath the lowermost beds of greensand ; thus occupying the same geological position as their English equivalents ; the total thickness of the series is estimated at 800 feet. Numerous characteristic fossils occur throughout these strata ; and even the principal subdivisions of the Sussex group have been distinguished.

During the last year, a beautiful work on the Wealden of the north of Germany, was published by Dr. Wilhelm Dunker, (of Cassel,) in which are numerous important additions to the fauna and flora of the country whence the wealden deposits were derived. It contains figures and descriptions of nearly fifty plants, and a still greater number of shells, several fishes, and two new reptiles ; the plants are chiefly ferns and cycadeæ.‡

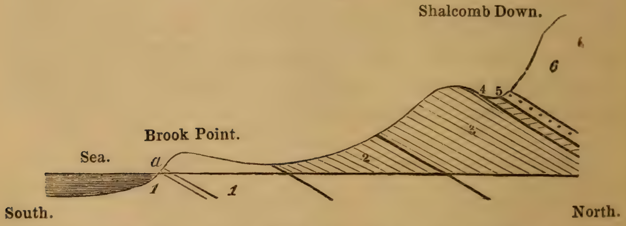
* Versteinerungen des Nord-deutschen Oolithen-Geberges; by Professor Römer: Hanover, 1836. In this work M. Römer enumerates many fossils which distinguish the Ashburnham *(der Ashburnham schichte)*, Hastings *(der Hastings sandstein)*, Tilgate *(Tilgat-stein)*, and Weald clay *(der Wëalder-thon)*, deposits. Cyprides, Paludinæ, Cyrenæ, Cyclades, &c. are mentioned as universally prevailing throughout the series.

† See Fossils of the South Downs, p. 34.

‡ Monographie der Nord-deutschen Wealdenbildung. Ein Beitrag zur Geognosie und Naturgeschichte der Vorwelt. Von Dr. Wilhelm Dunker. Brunswick, 1846. One vol. 4to. with twenty-one plates. This beautiful volume will of course find its way into the library of every geologist; but I would also strongly recommend it to the intelligent collector of organic remains, on account of the numerous and excellent figures of Wealden plants, shells, &c. The work may be obtained through M. Bailliere, Foreign Bookseller, Regent-street.

11. WEALDEN OF THE ISLE OF WIGHT.—Freshwater deposits similar to those we have described in Kent, Sussex, and Surrey, appear at the back, or along the southern shore, of the Isle of Wight; constituting the lowermost strata in that island, as shown in the section, *Lign.* 78, p. 364. These strata consist of clays, sands, and sandstones, with bands of shelly limestones, and grit; and are replete with the same species of river shells, terrestrial plants, and bones of reptiles, as the wealden of the S. E. of England. They form a line of low cliffs, in Sandown Bay, on the south-east of the island; and in the bay between Atherfield Point and Compton Bay, on the south-west.*

The relative position of the strata is shown in the annexed section, from the coast at Brook Point, to the chalk downs on the north. If we proceed from the sea-shore at Brook-chine, through the village of Brook, towards Shal-



LIGN. 80.—SECTION FROM BROOK POINT TO SHALCOMB DOWN; IN THE ISLE OF WIGHT.

1. Wealden beds. *a*. Fossil Trees. 2. Lower group of Greensand.
3. Upper group of Greensand. 4. Galt. 5. Firestone. 6. White Chalk.

comb-down, we pass over the beds in the following order. 1. Wealden clays, grits, &c. forming the cliff. 2 and 3. Greensand. 4. Galt. 5. Firestone. 6. Chalk.

* The reader is referred to my Geological Excursions round the Isle of Wight, for particular information on these strata, and their organic remains.

The Wealden beds form the entire cliff for several miles along this part of the coast; but they may be seen dipping under the lowermost sands of the cretaceous formation, near Compton-chine on the west of Brook Bay, and Atherfield Point on the east. Most of the peculiar fossils of the Wealden have been obtained from these shores; quantities of bones of enormous reptiles, freshwater shells, and crustaceans in immense quantities; river mussels of large size; and ferns and cycadeous plants. But the most remarkable phenomenon at Brook Point, is the occurrence at the foot of the cliff, of a prostrate forest of petrified pine-trees.

12. Fossil trees of the Wealden, at Brook Point. —The cliff at Brook Point is between thirty and forty feet high, and is capped by a thick bed of alluvial gravel and loam. It is composed of layers of clay and shale finely laminated, with thin seams and masses of lignite. The lower part of the cliff consists of beds of hard sandstone grit, resting upon mottled clays and sands, which are the lowermost wealden strata in the island. The fossil trees are imbedded in the sandstone, and protrude from the waterworn edges of the rock. This indurated grit forms a sort of buttress at the foot of the cliff, having resisted the tidal action which has carried away the upper and less coherent deposits: the numerous reefs that appear off the shore at low water, and render this coast so dangerous to mariners, have originated from this cause.

The trees are lying confusedly one upon another. There are no erect trunks, nor any other indications that the forest was submerged while growing in its native soil, like that of the Isle of Portland; on the contrary, the appearance both of the trunks in the sand-rock, and of those exposed to view by the removal of the materials in which they were originally imbedded, is that presented by the rafts that float down the great rivers of America; as for example the Ohio and Mississippi. Such rafts entangle in their course the remains of animals and plants that may happen to lie in the bed of the river, and at length subside and are engulfed in silt and sand; in like manner the fossil trees in this cliff are associated with river shells (*Uniones*), and bones of land reptiles. The fossil forest at Brook Point is, in fact, a raft of pine trees, which floated down the river that deposited the Wealden beds, and was submerged in its delta, burying with it bones of terrestrial animals, freshwater mussels, &c.

The trees when lying in the sandstone are invariably covered with their bark, now in the state of lignite, and which varies from one to three or four inches in thickness, according to the magnitude of the trunk. This carbonized cortical investment is quickly removed on exposure to the action of the waves; but the ligneous structure, the woody fibre, remains. The trees are calcareous, not siliceous like those of Portland; they are more or less traversed by pyrites, and the delicate veins and filaments of this mineral which permeate the woody fibre, impart a beautiful appearance to polished specimens. The trunks are generally of considerable magnitude, being from one to three feet in diameter; some are of such a size as to indicate a height of forty or fifty feet when entire. In the conversion of the bark into lignite, and in the smooth condition of the trunks, the trees of this fossil forest present a remarkable dissimilarity from those of the Isle of Portland, which we shall presently examine; for in the latter the carbonized bark rarely, if ever, occurs, and the surface of the stems is similar to that exhibited by the trunks of old decorticated trees, that have been much weathered by alternate exposure to air and moisture. At Brook Point, on the other hand, the trees appear to have been engulfed when fresh and vigorous, with their bark and vessels full of sap. The annular lines of growth are often very distinct, and I have traced from thirty to forty on some of the stems; but these circles are unequal, and indicate therefore a variation from year to year in the climate of the country in which they grew. The wood exhibits, under the microscope, the coniferous structure seen in the *Araucaria* (Norfolk Island Pine), the rows of glands or ducts being placed alternately; and the appearance is similar to that of the fossil wood of Willingdon in Sussex.* I observed no traces of the foliage or fruit of these trees, with the exception of a small cone, scarcely so large as that of the larch.† In the strata that overlie the fossil forest, thin interrupted seams and irregular masses of lignite, more or less impregnated with and permeated by iron pyrites, are very abundant.

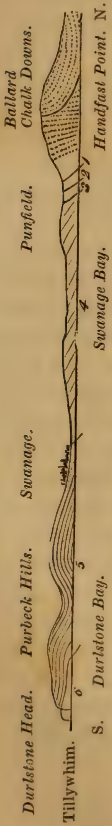
13. WEALDEN OF THE ISLE OF PURBECK.—The Wealden deposits are next seen in the Isle of Purbeck, the south-eastern part of Dorsetshire, which is distant about fifteen miles across the Channel, from the western extremity of the Isle of Wight. This island is an irregular oval area, between thirteen and fourteen miles in length, and seven in average breadth, from north to south. It consists of cretaceous, wealden, and oolitic strata, which occur in their natural order of succession, but highly inclined, in the section exposed in Swanage Bay, on the east of the island.‡ In this line of coast the geological structure of the Isle of Purbeck is clearly displayed. In Studland Bay, which is to the north of Swanage, the white chalk is seen to emerge from beneath the eocene strata, and form the cliffs; rising up into the range of downs that traverses the island from the east to the south-western shore. The curious flexures produced on the beds of chalk and flint by the elevations to which they have been subjected, are remarkably distinct at

* Medals of Creation, vol. i. p. 160.

† An account of the fossil bones, plants, &c. of the Wealden, which have been discovered along the coast in Brook and Brixton Bays, will be found in Excursions round the Isle of Wight, chap. x. and xi.

‡ Ibid. chap. xii.

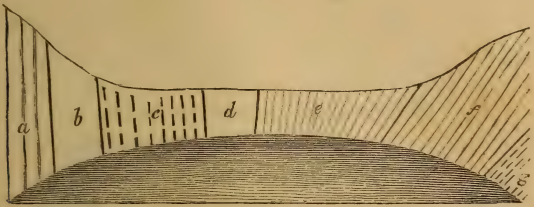
Handfast Point. The lower divisions of the chalk dipping at a considerable angle to the north, next appear ; and are followed by the Wealden clays, sands, &c. which stretch along Swanage Bay, to the elevated ridge of Purbeck strata, on the south of the little town of Swanage. At Durlstone Head a fine section of the Purbeck beds is exposed ; and at the extreme point, the Portland oolitic limestone appears. Purbeck has long been celebrated for its quarries, which have been worked from time immemorial, and particularly during the middle ages ; the compact varieties of the limestone, which take a good polish, having, under the name of Purbeck marble, been in great request for the religious edifices of that period ; and there is scarcely a cathedral or ancient church in England that does not contain columns, sepulchral monuments, or pavements, of this material. This marble (*Lign.* 96) is a congeries of small river snail shells, intermixed with the crustaceous cases of minute cyprides.



LIGN. 81.—SECTION ACROSS SWANAGE BAY; FROM BALLARD DOWN TO DURLSTONE HEAD:
(Distance about three miles.)
1. Firestone. 2. Galt. 3. Greensand. 4. Wealden. 5. Purbeck strata. 6. Portland Oolite.

14. COVES IN THE SOUTH-WEST OF THE ISLE OF PURBECK.—On the south-west coast of the Isle of Purbeck, the range of vertical chalk strata, the eastern extremity of which forms the high cliffs at Handfast Point (*Lign.* 81), reappears in several coves or inland recesses, which have been formed by the inroads of the sea ; no less than nine sections of the strata, from the

chalk to the oolite inclusive, being exposed along this coast, within a distance of five miles.* The subjoined diagram (*Lign.* 82) will explain the geological structure of these bays.



LIGN. 82.—PLAN OF THE COVES ON THE SOUTH-WEST COAST OF THE ISLE OF PURBECK.

a, Chalk. *b*, Firestone. *c*, Galt. *d*, Greensand. *e*, Wealden. *f*, Purbeck beds. *g*, Portland stone.

The northern barrier of the coves consists of precipitous chalk cliffs ; the entrance is formed by rocks of Portland and Purbeck limestone ; and between them is a low tract composed of the less durable wealden strata. These bays expose, in fact, transverse sections of the range of hills formed by the Portland and Purbeck beds ; and of the clays, sands, &c. of the Wealden ; and, at their back, precipices of great height, produced by the destruction of the southern face of the vertical chalk of the Downs.

Thus, within the distance of six or seven hundred yards, we may examine the entire series of strata, from the Chalk to the Portland oolite, by proceeding from the inland cliffs to the southern extremity of the bays ; the section of the east side of Lulworth Cove (*Lign.* 83) shows the relative position of the formations.

15. THE ISLE OF PORTLAND.—The island, or peninsula, of Portland, is a bold headland, off Weymouth, about four miles and a half in length, two in breadth, and

* Geol. Exc. Isle of Wight, p. 368—389.

300 feet high; it is united to the main land by a bank of shingle called the Chesil beach. It presents, on the north, a precipitous escarpment, and declining towards the south, appears, on approaching it from the east or west, like an insulated inclined plane, rising abruptly from the sea. The southern extremity is flanked by low calcareous cliffs, which, from the constant action of the sea, are worn into hollows and caverns. The base of the island is formed of a blue clay (*Kimmeridge clay*), surmounted by beds of sand; and on these are superimposed thick strata of the oolitic limestone, known as the *Portland stone*, which is extensively quarried in the northern brow of the island.

LIGN. 83.—SECTION OF THE EAST SIDE OF LULWORTH COVE.

The strata dip to the south at an angle which corresponds with the profile of the island. The coasts are steep, the base of Kimmeridge clay forming a talus, surmounted by perpendicular crags of oolite. The southern extremity consists of low oolitic limestone cliffs, which are worn into numerous caverns by the force of the waves.

The northern brow of the island, to a depth of upwards of twenty feet, is formed of finely laminated freshwater limestone, locally termed "*The Cap*," which belongs to the Purbeck system, and is superimposed on the uppermost bed of oolite. The Kimmeridge clay, which is the lowest visible deposit in the island, contains the usual marine shells, &c. that prevail in this bed in the Isle of

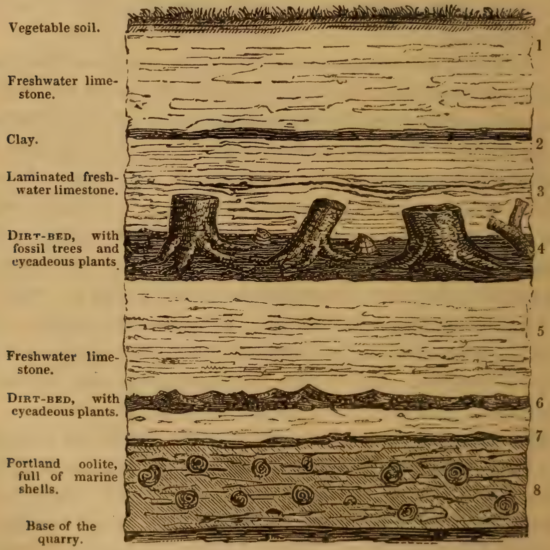
Purbeck,* and other parts of England. The oolitic limestone, which lies immediately upon the clay, contains nodules and veins of flint and chert. The middle group is full of the usual oolitic shells ; and the upper series, to within twenty feet of the surface, consists of the fine architectural stone which is locally termed the *white-bed.* Upon this is a stratum, three or four feet thick, of limestone, full of cavities left by numerous shells, of which the casts only remain ; and above is an irregular layer of flint nodules, in coarse oolite, which is covered by a thin bed of earthy detritus.

16. The petrified forest of Portland.—The freshwater strata which form the northern brow of the Isle of Portland, belong to the lowermost beds of the Purbeck group of the Wealden formation. They are in fact the first sediments that were deposited by the body of fresh water, which covered for ages the ancient oolitic rocks ; and they indicate the commencement of the delta, which ultimately spread over a great part of England and northern Germany ; they are therefore, in every point of view, in the highest degree interesting. The annexed section of a quarry (*Lign.* 84) in which these strata are seen in their natural position, will serve to exemplify the following remarks.

The lowermost beds in this quarry consist of the Portland building stone (8) ; and upon these are layers of rubbly oolite (7), covered by a thin seam of black earth, with interspersed vegetable matter, in which fossil cycadeous plants have been discovered. This is succeeded by laminated freshwater limestone (5), upon which is the remarkable stratum, called "*Dirt-bed*" (4), by the quarrymen. This bed is about one foot in thickness, and consists of a dark brown friable loam, containing a large proportion of earthy lignite, and like the modern soil of the Island, many

* Geol. Exc. Isle of Wight, p. 401.

waterworn stones, and pebbles. This stratum appears to have been a bed of vegetable mould which supported a luxuriant flora; for in and upon it are numerous trunks and branches of coniferous trees, and cycadeous plants. Above the dirt-bed are finely laminated cream coloured limestones (3, 2, 1), the total thickness of which is about ten feet; in these beds a few cyprides are the only organic remains that have been observed. These limestones are covered by the modern vegetable soil, which but little exceeds in depth the



Total thickness about thirty feet.

Lign. 84.—Section of a quarry in the Isle of Portland.*

ancient one, above mentioned; and instead of supporting cycadeous plants and pine forests, barely maintains a scanty

* From Dr. Fitton's Memoir on the Strata below the Chalk. Geological Trans. vol. iv.

vegetation, there being but few trees or shrubs in the whole Island.

But the most remarkable fact which this section presents, is the position of the trees and plants in the Dirt-bed ; for they are still erect, as if they had been petrified while growing in their native forests, with their roots in the vegetable soil, and their trunks extending into the limestone above (*Lign.* 84, 4, 3,). As the Portland building stone lies beneath the freshwater strata, which are but little employed for economical purposes, the petrified trees are removed, and thrown by as rubbish. On one of my visits to the island (in the summer of 1832), the surface of a large area of the dirt-bed was cleared, preparatory to its removal, and the appearance presented was most striking. The floor of the quarry was literally strewn with fossil wood, and before me was a petrified forest, the trees and the plants, like the inhabitants of the city in Arabian story, being converted into stone, yet still remaining in the places which they occupied when alive ! Some of the trunks were surrounded by a conical mound of calcareous earth, which had evidently, when in the state of mud, accumulated round the stems and roots. The upright trunks were generally a few feet apart, and but three or four feet high ; their summits were broken and splintered, as if they had been snapped or wrenched off by a hurricane at a short distance from the ground. Some were two feet in diameter, and the united fragments of one of the prostrate trunks indicated a total length of from 30 to 40 feet; in many specimens portions of the branches remained attached to the stem. In the *Dirt-bed*, there were numerous trunks lying prostrate, and fragments of branches.

The external surface of all the trees I examined was weatherworn, and resembled that of posts and timbers of groins or piers within reach of the tides, and subjected to the alternate influence of the water and atmosphere ; there are but seldom any vestiges of the bark.

17. Fossil Cycadeæ :—Mantellia.—The fossil plants

related to the recent *Cycas and Zamia*,* occur in the intervals between the pine-trees ; and the dirt-bed is so little consolidated, that I dug up with a spade, as from a parterre, several specimens that were standing on the very spot where they originally grew, having, like the columns of the Temple of Puzzuoli (p. 107), preserved their original

LIGN. 85.—SILICIFIED TRUNK OF MANTELLIA NIDIFORMIS, FROM PORTLAND; *one-fourth the natural size.*

(Cycadites megalophyllus, Dr. Buckland.)

a, Central mass of cellular tissue ; *b*, Circle of radiating woody plates ; *c*, Zone of cellular tissue ; *d*, The case, or false bark.

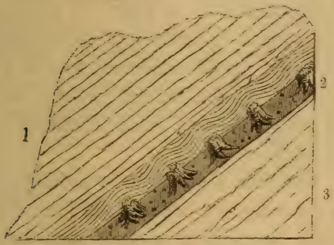
erect position, amidst all the revolutions which have subsequently swept over the surface of the earth, and buried them beneath the accumulated detritus of innumerable ages.

These fossil plants, though related to the recent Cycadeæ,

* These plants are so common in conservatories that their general appearance must be familiar to the reader. In the botanic gardens at Kew, there are magnificent specimens of Cycas and Zamia, and of other plants of hot climates, of which related forms occur in the Wealden.

belong to a distinct genus.* There are two species; one is short, and of a spheroidal form (*M. nidiformis*, *Lign.* 85); the other is longer, and subcylindrical (*M. cylindrica*†).

The trees and plants are completely silicified; and their internal structure is beautifully preserved in many examples; the wood, microscopically examined, displays the organization of the Araucaria. A cone has been found in the Dirt-bed, which Dr. Brown considers to be nearly related to the fruit of the Norfolk Island pine (*Araucaria excelsa*). The Portland and Isle of Wight fossil trees, appear to belong to the same species of coniferæ.



LIGN. 86.—SECTION OF THE CLIFF ON THE EAST OF LULWORTH COVE.
1, Purbeck calcareous slate; 2, Dirt-bed, with trunks of trees; 3, Oolitic limestone of Portland.

18. DIRT-BED OF PURBECK.—The Dirt-bed extends through the northern part of the Isle of Portland, and appears on the coast of Purbeck under circumstances of peculiar interest. In the highly inclined strata of the cliff, about a furlong to the east of Lulworth Cove, a considerable number of petrified trees is exposed, under similar conditions with those of the Portland quarries. The lowermost strata (*Lign.* 86, 3), are the Portland oolitic

* Named by M. Adolphe Brongniart, *Mantellia.*

† Specimens of the former species are called "*Crows' nests*" by the quarrymen; who believe them to be birds' nests, originally built by crows in the pine-trees, and which have since become petrified.

limestones, full of marine shells ; upon these is the dirt-bed with fossil trees (2) ; this is covered by cream-coloured calcareous stone in thin undulated laminæ, locally termed "*soft-burr*" (1) ; and above are shales and narrow bands of limestone, belonging to the lower series of the Purbeck.

The dirt-bed has been discovered by Dr. Buckland near Thame in Oxfordshire ; and by Dr. Fitton, in the Vale of Wardour. It also occurs at Swindon in Wiltshire on the top of the Portland oolite, where fossil coniferous wood is found in abundance, and a few examples of Mantellia have been obtained. Between Stone and Hartwell in Buckinghamshire, a seam of carbonaceous earth occupies the geological position of the Portland dirt-bed, and is covered by cream-coloured marls and limestones resembling the *Cap*, in which wings of insects, and leaflets of Wealden ferns, with remains of very small fishes, have been discovered.*

From what has been stated, it is evident, that after the marine strata forming the base of the Isle of Portland were deposited at the bottom of a deep sea, and had become consolidated, the bed of that ocean was elevated above the level of the waters, and constituted an island, or archipelago, covered with pine forests, and cycadeous plants. How long this new country existed, cannot be ascertained, but that it flourished for a considerable period is certain, from the number and magnitude of the petrified trees.†

* See History of Fossil Insects in the secondary rocks of England, by the Rev. P. B. Brodie.

† *Modern submerged Forest.*—An interesting modern example of the subsidence of a considerable tract of country clothed with forests, the trees remaining erect, although submerged beneath a river which still flows over them, is described by a late American writer, and will serve to illustrate the remarks in the text. The whole district, from the Rocky Mountains on the east and the Pacific Ocean on the west, and from Queen Charlotte's Island on the north to California on the south, presents one vast tract of volcanic formation. Basalt—both

19. Organic remains of the Wealden.—The fossils of the Wealden consist of leaves, stems and branches of plants of a tropical character; bones of enormous terrestrial reptiles of extinct genera, and of turtles, flying reptiles, and birds; remains of fishes of several genera and species; and numerous fluviatile shells and crustaceans.

The bones are, for the most part, broken and rolled, as if they had been transported from a distance. They are more or less impregnated with iron, and commonly of a dark brown colour. Those in loose sand and sandstone are often porous and friable; those in the Tilgate grit, heavy, brittle, and with the internal structure well preserved; in fractured portions imbedded in the limestone, the interstices are filled with white calcareous spar, and the cancellated structure of the bones is frequently permeated by the same substance.

The fossil vegetables occur either bitumenized, or in the state of sandstone casts; carbonized leaves and twigs are abundant in some of the strata, and the stems and branches are sometimes silicified.

columnar and in amorphous masses, veins and dykes—every where occurs, and craters of extinct volcanoes are still visible. Elevations and dislocations of the strata have taken place on an immense scale; and successive beds of basalt, amygdaloidal trap, and breccia, prove the alternation of igneous action and periods of repose. Within a few miles of the cascades of the river Columbia, and extending upwards of twenty miles, trees are seen standing in their natural position, in a depth of water from twenty to thirty feet. The trees reach to high, or fresh-water mark, which is fifteen feet above the lowest level of the tide; but they do not project beyond the freshet rise, above which their tops are decayed and gone. In many places the trees are so numerous, that "we had to pick our way with the canoe, as through a forest. The water of the river was so clear, that the position of the trees could be distinctly seen down to their spreading roots, and they are standing as in their natural state, before the country had become submerged. Their undisturbed position proves that the subsidence must have taken place in a tranquil manner."—*Journal of an Exploring Tour beyond the Rocky Mountains*, by the Rev. Samuel Parker, A.M. New York. 1838.

The shells in the clays have undergone but little change, and in many examples, the epidermis and even ligament are preserved; in the limestones, the substance of the shells is converted into spathose carbonate of lime; in the sandstones, casts of the interior of the shells are often the only vestiges. With these general remarks, I pass to the consideration of the fauna and flora of the Wealden epoch.

20. FOSSIL VEGETABLES.—From the abundance of carbonized vegetable remains in many of the laminated shales and clays, and the occurrence of *lignite*, or brown-coal, in masses and layers, which sometimes alternate with shales abounding in fresh-water bivalves, a striking analogy is presented to some of the divisions of the *Coal measures;* but there are no beds of coal of any economical value in the English Wealden.* In Hanover, however, this formation contains an extensive coal field, which furnishes excellent fuel.

But notwithstanding the prevalence of vegetable matter in the strata, specimens exhibiting the internal structure of the plants, with any tolerable distinctness, are very rare; and though my researches were for many years unremitting, I have obtained but few fossil plants that admit of satisfactory conclusions as to the organization and affinities of the originals. I shall restrict my observations to a brief account of the principal kinds, and the circumstances under which they occur.

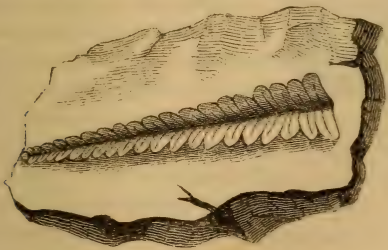
Ferns.—Entire layers of the calciferous grit of Tilgate Forest are so full of minute portions of carbonaceous matter,† as to present a dark mottled colour; and upon examining the imbedded particles, they prove to be the detritus of plants ground to pieces by agitation in water loaded with sand and mud. Specimens in my possession

* See Geology of the South-East of England, p. xviii.; and Fossils of the South Downs, p. 35, for an account of an unsuccessful trial for coal at Bexhill.

† Fossils of Tilgate Forest, Plate 3, *fig.* 6.

show that they have been principally derived from two elegant extinct species of ferns, which are peculiar to the Wealden. The one is characterized by its slender and minutely divided wedge-shaped leaflets (*Sphenopteris Mantelli*, *Lign.* 87); the other by the distribution of the nervures or veins (*Lonchopteris Mantelli*, *Lign.* 88), the long and many times pinnated leaves, and the reticulated disposition of the secondary veins that spring from the mid-rib of the leaflets. This plant has also been found in the valley of Bray, in the lower Boulonnais, by M. Graves of Beauvais (p. 227); and in Sweden, in strata supposed to be of the same epoch as the wealden. The Lonchopteris likewise occurs high up in the greensand strata, at Atherfield and Shanklin chine in the Isle of Wight.*

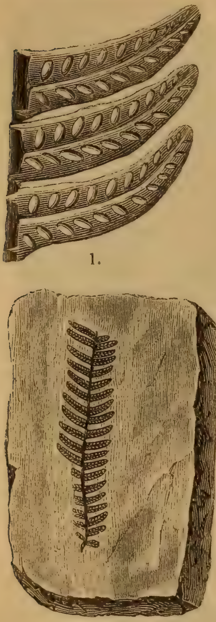
Lign. 87.—Sphenopteris Mantelli. Tilgate Forest.



Lign. 88.—Lonchopteris Mantelli. Tilgate Forest.

* It was first noticed in this geological position by Mr. John Morris. Geol. Exc. Isle of Wight, p. 230.

These ferns probably did not attain a considerable magnitude. The largest stem of the *Sphenopteris* I have seen, must have belonged to a plant about five or six feet high. Several other species of ferns are associated with these remains; but the two plants above named, constitute by far the greatest proportion of the fossil vegetables of Tilgate Forest. I have a remarkable specimen of another fern, in which the parts of fructification are beautifully preserved (*Lign.* 89); the same species has been found in the Wealden of the north of Germany.* Obscure indications of other species of ferns occur in our wealden clays, but no intelligible specimens have been obtained. In the German deposits Dr. Dunker has discovered upwards of twenty species.†



LIGN. 89.—FROND OF A FERN IN FRUCTIFICATION; IN SANDSTONE, FROM TILGATE FOREST.

(*Alethopteris elegans; of Dr. Dunker.*)

Fig. 1. Three pinnules magnified.

Fig. 2. The specimen of the natural size.

Leaves of Cycadeous plants, and seed-vessels of *Restiaceæ*, are met with in the ironstone of Heathfield, Sussex; and remains of the foliage of trees allied to the Cypress and Juniper. The stems of a species of Equisetum *(mare's tail)* abound in the blue limestone of Pounceford.‡

21. CYCADEOUS PLANTS.—*Endogenites erosa.*§—In the strata of Tilgate Forest, in the sands of Hastings,

* Monographie der Nord-deutschen Wealdenbildung, Pl. VII. *fig.* 7.

† Ibid. p. 28.

‡ *Equisetum Lyellii*; Med. Creat. vol. i. p. 108.

§ Fossils of Tilgate Forest, Pl. III. III*.

and in the clays of Germany,* many specimens of the stems of a very curious plant, formerly supposed to be related to the *Euphorbia*, or *Cacti*, have been discovered. These stems are of various forms; some are cylindrical, and tapering at both ends; others are flattened, and of a clavated shape. The constituent substance is a grey, compact, subcrystalline sandstone, and the external surface of the stems is traversed by fine meandering grooves, and deep tubular furrows, lined with minute quartz crystals; a transverse section exhibits the surface covered by small pores, and a few large openings, the sections of the tubes. In a specimen which I picked up on the beach at Brook Point, bundles of vascular tissue are preserved; these are disposed in a flexuous zone round the margin of the stem. The plant is supposed by Dr. Brown to be allied to the Cycadeæ.† Cones and stems of a species of Zamia have been found with bones of the Iguanodon in Sandown Bay.‡

22. Clathraria Lyellii (*Ligns.* 92, 93).—The most interesting plant belonging to this tribe of coniferæ, of which any vestiges have been found in the Wealden, is that first discovered by me in Sussex, and described under the name of *Clathraria Lyellii.*§

The fossil remains consist of portions of the stem, scored by the imprints left by the attachment of the petioles; leaf-stalks; the internal axis; and obscure indications of the foliage and seeds. || The stem is composed of an axis, having the surface covered with reticulated fibres; and of a false bark, produced by the union of the consolidated bases of the petioles, the insertions of which are rhomboidal and transverse.

* Mon. Nord. Weald. Tab. III.

† See Geology of the Isle of Wight, p. 288.

‡ Medals of Creation, vol. i. p. 160.

§ Fossils of Tilgate Forest, Pl. I. II. and III. and Geol. of the S. E. of England, Pl. I.

|| Medals of Creation, vol. i. p. 182.

The external surface is in consequence marked with lozenge-shaped elevated scars, separated from each other by lateral depressions, surrounded by a parallel band of a fibrous structure (see *Lign.* 90). This outer portion is sometimes consolidated into a compact cylinder of stone, which will separate from the central axis.* The latter is solid, and strongly marked externally with reticulated interrupted ridges. This surface has generally patches of vascular tissue adhering to it; and on some parts of the internal axis there are deep pits, indicating lacunæ which probably contained a resinous secretion, as in the Dragon-blood plant. In a waterworn specimen collected from the beach at Brook Point (*Lign.* 90), the internal structure, which is seen in thin transverse sections, resembles that of the Cycadeæ.

LIGN. 90.—PORTION OF THE STEM OF CLATHRARIA LYELLII; FROM BROOK BAY.

(One-third linear nat. size.)

The most interesting example hitherto known was obtained from a stratum of chalk marl at Bonchurch in the Isle of Wight.† It consists of the summit of the stem garnished with persistent petioles, as shown in the annexed figure, *Lign.* 91. The original is fifteen inches in length; the upper part is entire, but the lower is broken, and exposes the internal axis in its natural position (*a*), surrounded by the false bark, formed by the consolidation of the bases of the leaf stalks. The surface of the lower portion of the stem is bare, and scored with the lattice-like cicatrices,

* Fossils of Tilgate Forest, Plate II.

† Geology of the Isle of Wight, p. 294.

whence the name, *Clathraria*, is derived: but the upper $10\frac{1}{2}$ inches is covered by the petioles, some of which are abortive, being entire and rounded above; while others

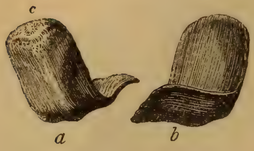
LIGN. 91.—SUMMIT OF A STEM OF CLATHRARIA LYELLII;

From the Chalk-marl at Bonchurch, Isle of Wight; discovered by CAPTAIN IBBETSON.

This fossil is the summit of a stem garnished with petioles or leaf-stalks on the upper part: from the lower portion the petioles have been removed. The internal axis is seen at *a*. The original is fifteen inches in length; and eleven and a half in the widest transverse diameter. It is deposited in the collection of the Isle of Wight Fossils, in the Polytechnic Institution, London.

have their summits marked with vascular pits, disposed with great regularity, as shown in *Lign.* 92, *c;* these indicate the former attachment of leaves, that were shed naturally. Similar characters are observable in the petioles of the recent Zamiæ;* the presence of this characteristic plant of the Wealden so high up in the chalk formation is in accordance with the occurrence of bones of the Iguanodon, &c. in the greensand of Kent, which we shall notice hereafter.

In the strata of Tilgate Forest, the Clathrariæ are invariably associated with waterworn bones of reptiles, pebbles, gravel, and other drift; and are often imbedded in the fluviatile conglomerate which is found in some parts of the Wealden. They appear to have floated down the river with the carcasses and limbs of the reptiles, and at length to have sunk to the bottom, and become imbedded in the mud of the delta.



LIGN. 92.—A PETIOLE OF CLATHRARIA LYELLII; *from the stem of the specimen figured Lign.* 91.

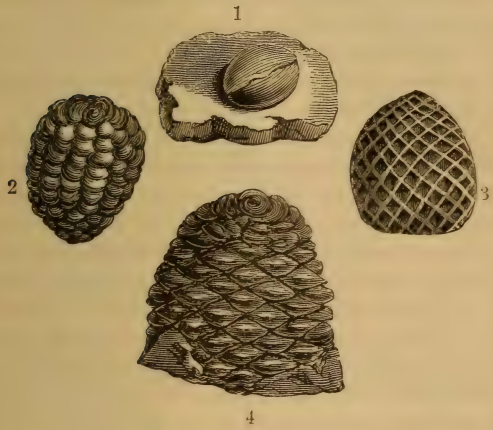
a, The external surface; *b*, the internal surface; *c*, the vascular markings, left on the summit by the separation of the leaf.

A cluster of petioles belonging to a large plant of the Clathraria, has recently been discovered in the greensand near Maidstone; in the same quarry of Kentish-rag in which were found, some years since, a considerable portion of the skeleton of an Iguanodon, associated with drifted coniferous wood, and other vegetable remains. I have collected a few detached petioles of Clathraria from the chalk marl, and white chalk, near Lewes.

23. FRUITS OF CONIFERÆ.—The seed-vessels of several coniferous trees and plants have been discovered in the Wealden, but under circumstances which render it impos-

* In a flourishing old plant of the *Encephalartus pungens* from South Africa, in the botanic gardens at Kew, all the lower part of the stem, beneath the coronet of foliage, is covered with persistent petioles; those which have borne leaves have vascular pits on the summit, but the abortive petioles are smooth and entire at the apex.

sible to determine whether they belong to the same species as the stems and leaves that occur with them. Several cones of a species of Cycas or Zamia were found with bones of the Iguanodon in Sandown bay.*



Lign. 93.—Fossil fruits from the Wealden.

Fig 1. Supposed seed-vessel of Clathraria Lyellii. 2. Cone from the Isle of Purbeck. 3. Cone from Kent. 4. Cone from Pippingford, Sussex.†

A considerable number of small oval nuts or carpolithes (*Lign.* 93, *fig.* 1), have been obtained from the Tilgate grit; these are considered by M. Adolphe Brongniart as probably belonging to the Clathraria.

The fossil fruits or cones figured in *Lign.* 93, *figs.* 2, 3, 4, are evidently referable to different kinds of coniferous trees.

* Geology of the Isle of Wight, p. 138. One of these cones is figured in Medals of Creation, vol. i. p. 160.

† Figs. 2, 3, 4, are reduced one-half from Dr. Fitton's Memoir, Pl. XXII. Geolog. Trans. vol. iv.

The specimen from Sussex, *fig.*4, is remarkable for the double prominences on the scales. I extracted a small cone from the lignite beds at Brook Cliff, which may possibly be the fruit of the pine-trees of the fossil forest in that locality: a cone resembling that of the Norfolk Island Pine has been found in the dirt-bed of Portland.

Four small carpolithes, and leaves of nine or ten (supposed) species of cycadeous plants, are described and figured by Dr. Dunker, from the Wealden of Germany.*

24. UNIVALVE SHELLS OF THE WEALDEN.—The durable remains of molluscous animals are most abundant; thick beds of limestone, spread over wide areas, and chiefly composed of but three or four species of bivalves and univalves, being a constant character of this group of deposits. The prevalent shells belong to a few common fresh-water forms, as *Paludina, Cyclas, Unio;* three or four other fluviatile, and an equal number of marine genera, the latter being very sparingly distributed, make up the conchology of the Wealden. Of the *Cyclas*, a fresh-water bivalve which we have already noticed as abounding in certain tertiary strata, upwards of forty species have been determined: of the *Unio*, a well-known fluviatile mussel, ten or twelve species: and of the river snails, the ***Paludinæ***, a like number. It is worthy of remark, that of the common lacustrine snails, the *Limnæa*, so abundant in the fresh-water tertiary beds of the Isle of Wight, but one wealden species is known; and of the *Planorbis*, its constant associate in those deposits, and in our ponds and lakes, one only has been detected.† The conchological fauna of the Wealden is, in fact, rigidly fluviatile. In some parts of the lower beds, layers of oysters occur, and occasionally a stray marine

* Mon. Nord. Weald. Tab. II. IV. VII. pp. 16, 21.

† Ibid. Tab. X. figs. 1, 2. *Planorbis Inglesi*, and *Limnæa Hennei*, of Dr. Dunker.

shell is found entangled in the fresh-water sediments; but, I repeat, the shells hitherto discovered afford no grounds for invalidating my original statement,* that the Wealden is an ancient delta—a fluviatile formation.

The most abundant shells of this division of testaceous mollusca are the *Paludinæ*, of which the Sussex and Pur-

LIGN. 94.—UNIVALVE SHELLS OF THE WEALDEN.

Fig. 1. Paludina Sussexiensis. 2. Melanopsis.
3. Neritina Fittoni; *a, natural size.*

beck marbles are almost wholly made up: the former limestone differing from the latter, simply in the species of which it is composed.

The Sussex marble is a congeries of paludinæ; chiefly of *Paludina fluviorum* and *P. Sussexiensis* (*Lign.* 94, *fig.* 1.). In the coarse varieties of this stone, the shells are decomposed, and the interstices left by their removal filled up with clay; but in the compact layers and blocks, the shells are transmuted into calcareous spar, and their cavities contain indurated marl and limestone, of various shades of grey, blue, yellow, &c. interspersed with pure white, mottled with black; the polished slabs (*Lign.* 95) display innumerable sections of the inclosed shells, and rival in interest and beauty many of the foreign marbles. The black and dark brown spots and veins in this and other shelly marbles, have originated from the transmutation of the soft bodies of the mollusca into a carbonaceous

* In 1822.

substance, termed *molluskite*.* The shells, which were empty at the period of their becoming imbedded, had their

LIGN. 95.—POLISHED SLAB OF SUSSEX MARBLE.
(*Composed of Paludinæ and Cyprides.*)

cavities filled with mud, silt, or other detritus, which has subsequently hardened into clay, marl, limestone, &c.: but those which contained the gelatinous bodies of the snails, are occupied by a mass consisting of carbon, and a large proportion of phosphate of lime. In the polished sections of the marble, this carbonaceous animal matter often appears in black or dark brown spots and veins: and the most beautiful slabs owe their variegated appearance to the contrast produced by the molluskite with the white calcareous spar. Upon examining thin slices of this marble under a slightly magnifying power, many of the shells, and the interstices between them, are seen to be filled up with the cases of *Cyprides* (*Lign.* 98).

* See Medals of Creation, vol. i. p. 431. Geology of the Isle of Wight, p. 248.

The Purbeck marble differs from that above described, in being composed of smaller shells of the same genus (*Paludina elongata*); it also contains abundance of cyprides; and in some layers, small bivalves (*Uniones*), replaced by white spar, give a variety to the markings exposed in the sections. The polished cluster-columns in the Temple Church in London, and in Chichester Cathedral, and many of the monuments in Westminster Abbey, are of this marble; in other words, they are constructed of conglomerated masses of petrified shells of snails, which lived and died in the rivers that flowed through a country inhabited by the Iguanodon and other extinct colossal reptiles, ages before a single layer of the chalk was deposited!

LIGN. 96.—POLISHED SLAB OF PURBECK MARBLE.
(*Composed of a small species of Paludina.*)

A few species of an elongated spiral freshwater univalve (*Melanopsis*), are found in great perfection in some of the clays at Pounceford (*Lign.* 97, *a*), associated with the characteristic bivalves of the wealden (*Lign.* 97, *b* and *c*). A few specimens of a small elegant Nerite (*Neritina Fittoni*, *Lign.* 94, *fig.* 3), have been found in the calciferous grit of Tilgate Forest and Hastings.

25. BIVALVE SHELLS.—We have already had occasion to observe that many kinds of the bluish grey limestones of the Wealden, are largely composed of small bivalves of the genera *Cyclas* and *Cyrena*; some layers form a compact marble that will bear a good polish. In the clay the shells are often beautifully preserved; as in these specimens from Pounceford (*Lign.* 97), in which the epidermis and ligament remain.

The fresh-water mussels called *Uniones*, from their solid pearly shells, occur in considerable abundance in some of

LIGN. 97.—WEALDEN SHELLS, FROM POUNCEFORD, SUSSEX.

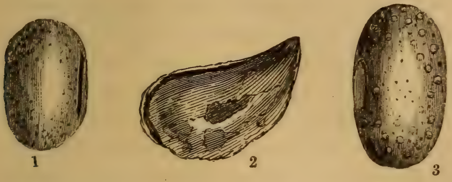
a, Melanopsis tricarinata;* *b*, Cyclas media; *c*, Cyclas membranacea.

the Wealden strata, but the species are, for the most part, of small size. But I discovered, not long since, a remarkably fine and large Unio, in the cliff at Brook Point, imbedded with the fossil trees (*ante*, p. 379). I have named it *Unio Valdensis*, or Wealden mussel. These shells are from four to six inches long, and well preserved; the surface is of a tawny red colour, the horny ligament, with its transverse rugæ remains, and in some examples the shells are occupied by the body of the animal in the state of molluskite.† The collocation of these large mussels with the drifted trees and bones of terrestrial reptiles, in strata so manifestly of fluviatile origin, completes the analogy between the rafts imbedded in the delta of the wealden,

* This shell is the Potamides carbonarius of Römer, and is abundant in weald clay at Neurladt, in Hanover.

† See Geology of the Isle of Wight, p. 303, for the description, and Pl. VI. *fig.* 1, for a figure of this fine fossil shell, which resembles some of the Uniones of the American rivers. Also the London Journal of Geology; Plate XIV.

and those brought down, and engulfed in mud and sand, by the Ohio and Mississippi, and other large rivers.



LIGN. 98.—CRUSTACEANS AND SHELL, FROM THE WEALDEN.

Figs. 1 and 3. Cypris granulosa; *highly magnified.*
2. Mytilus Lyellii; *one-third natural size.*

A few small freshwater mussels occur in the clay at Pounceford, associated with cyclades ; a species is figured in *Lign.* 98, *fig.* 2.

26. CRUSTACEANS OF THE WEALDEN.*—The crustaceans of the Wealden, though occurring in inconceivable numbers, belong to but two kinds ; viz. *Archœoniscus* and *Cypris.* The first are referable to the isopodous order, of which our common *Oniscus*, or wood-louse, is an example ; but the fossil *Isopoda* were aquatic. They were discovered by Mr. Brodie, with remains of insects, in grey marly Purbeck limestone, near Dinton.†

The Cyprides are very small crustaceans, having the body inclosed in a horny bivalve shell or case, united by a hinge, and admitting the antennæ and feet to protrude and be at liberty, when the case is open. They have only one eye, situated in the middle of the head ; the species which abound in our pools of fresh-water have two pairs of pats or feet ; those of brackish and salt-water *(Cytherina)* have three pairs, and inferior antennæ ; but the shells are so alike, that the lacus-

* Medals of Creation, vol. ii. p. 544.
† Ibid. p. 542 ; and History of Insects, p. 10.

trine and marine forms cannot be distinguished in a fossil state: the nature of the originals can only be inferred by the organic remains with which they are collocated. Like other crustaceans they frequently shed their cases, and the mud spread over the bottoms of still lakes is often covered with their exuviæ.. The largest living Cypris does not exceed one sixth of an inch in length. In a fossil state their cases appear like white elliptical reniform scales, on the surface of the recently separated laminæ of clay, shale, and limestone. Upon exposure to the air the cases decompose, and leave the surface of the shale or stone covered with the casts of the shells, which appear as minute polished tubercles; some layers of the indurated ironstone have a granulated surface from these remains.* In the Sussex and Purbeck marbles, as previously mentioned, the cyprides are most abundant. There are several fossil species, one of which is represented very highly magnified in *Lign.* 98, *figs.* 1, 3.

As the recent species inhabit either still lakes or gently flowing streams, and not the turbulent waters of estuaries, it follows that sediments largely charged with these exuviæ, associated with freshwater shells, afford strong presumptive evidence of a fluviatile origin.

27. INSECTS OF THE WEALDEN.—The durable nature of the wing-cases (*elytra*), legs, antennæ, &c. of the coleoptera, and other insects, rendered it probable that some vestiges of this class of articulated animals would be preserved in the muddy sediments of the Wealden. But I sought in vain for any vestiges of this kind, in the localities of the south-east of England that were accessible to my observations. In the remote outliers of the Purbeck beds in the vale of Wardour in Wilts, and in several places in

* In the sandstone quarries at Langton Green, near Tunbridge Wells, slabs of this kind occur, studded over with casts of cyprides, and minute uniones.

Buckinghamshire, the researches of the Rev. P. B. Brodie have been most successful, and the acumen and perseverance of that gentleman have brought to light several hundred specimens of insects or parts of insects. These consist chiefly of remains of *Coleopterous, Orthopterous,* and *Hemipterous* insects ; and several kinds of *Diptera* and *Neuroptera.* I have subsequently collected a few relics of beetles from the Wealden marls at Wateringbury near Maidstone ; and of coleoptera, diptera, and some unknown forms, from near Stone in Buckinghamshire ; a locality of fossil insects first pointed out by Mr. Brodie.

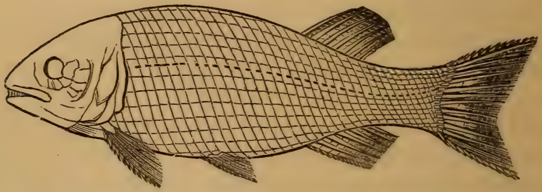
The Wealden insects hitherto discovered are of very small size, especially the Diptera and Coleoptera ; and if any inferences could be legitimately drawn from these limited observations, a low climatorial temperature of the country they inhabited would be indicated, as the magnitude of the insect tribes is in proportion to the heat of the climate. The insects discovered by Mr. Brodie, and described and figured by Mr. Westwood, comprise species of *Aphis,* cuckoo-spit insects (*Cercopidæ*), diamond beetles (*Curculionidæ*), terrestrial Crickets, Cockroaches, and Dragonflies (*Libellulæ*) ; of the latter, which are inhabitants of the water in their first stage, and of the air in their last, there are relics belonging to species of gigantic size. As a general result, Mr. Westwood considers the entomological fauna of the Wealden to indicate a temperate climate.* At the same time we must remark, that it is not at all probable that the annulosa of the wealden epoch are wholly represented by the minute and fragmentary remains at present known.

28. Fishes of the Wealden.—The fishes whose relics are distributed throughout the Wealden formation

* From Mr. Westwood's observations, in the elegant volume entitled, A History of the Fossil Insects of the Secondary Rocks of England, by the Rev. P. B. Brodie; one vol. 8vo. 10 plates. Van Voorst, 1845.

are, for the most part, either of the shark family, or of related genera; and of species allied to the large river-pikes of South America. Detached scales, teeth, dorsal rays, and bones of these fishes are very abundant; but it is rarely that united portions, either of the skeleton, or of the dermal covering, are preserved.

Strong thick enamelled scales, bearing a high polish and having two processes of attachment, with small hemi-spherical teeth, called by the workmen *fishes' eyes*, are the



Lign. 99.—Restored outline of the Lepidotus of the Wealden.
(By M. Agassiz.)

most common relics of this kind.* They belong to the *Lepidotus*, or bony pike, a genus of which a living representative inhabits the rivers of South America. In the grits and conglomerates of Tilgate Forest, and of Hastings, these scales and teeth are in prodigious numbers. A few tolerably perfect specimens of the fishes from which these teeth and scales were derived have been obtained, and have enabled M. Agassiz to determine the form of the original (*Lign.* 99).† In the Purbeck strata a small species of Lepidotus is equally abundant.

* Medals of Creation, vol. ii. p. 637.

† A specimen in the British Museum (from my collection) has a considerable part of the cranium and body, with the dorsal and pectoral fins. Another (discovered by Robert Trotter, Esq. formerly of Borde Hill, Sussex) retains a mass of the scales in juxtaposition, more than a foot wide, near where the caudal fin commences; this fish must therefore have been ten or twelve feet long, and three feet wide.

Finely striated tricuspid teeth, and others of a transversely elongated shape, with a sharp elevated central cusp and several small lateral ones, are the next in frequency. These belong to fishes termed *Hybodonts*, allied to the sharks, from which they did not materially differ in their habits and economy. They possessed two dorsal spines or rays, and remains of these appendages are occasionally met with in the Tilgate grit and Hastings sandstone.*

I have found in the Tilgate grit a few small oblong teeth, with the surface of the crown covered by fine radiating striæ; these are referable to another genus of squaloid fishes (*Acrodus*†), related to the Port-Jackson shark.

Small palatine bones, having a median row of flat transversely arched dental plates, with two rows of hemispherical obtuse teeth on the sides, are occasionally found in the quarries around Tilgate Forest, Horsham, and Hastings. These belong to fishes of the genus *Pycnodus*, so named from the thickness of their teeth, which are constructed for crushing hard substances. I have not observed any other determinable parts of these fishes.‡

Two very small fishes, belonging to the genus *Leptolepis*, and two others equally minute, which are supposed to indicate new generic characters, were discovered by Mr. Brodie, in the strata containing insects, near Dinton, in the Vale of Wardour.§

29. Reptiles of the Wealden.—It will doubtless surprise the reader to learn that the whole of the enormous bones and teeth before us, are those of reptiles,‖ and that

* Medals of Creation, vol. ii. p. 607, 621. Fossils of Tilgate Forest, Pl. V. *fig* 14; Pl. XV. *fig.* 2.

† Medals of Creation, vol. ii. p. 614. ‡ Ibid. p. 641.

§ History of Fossil Insects, Pl. I. *figs.* 1, 2, 3, 4; p. 15.

‖ This Lecture was illustrated by several hundred specimens of bones and teeth of reptiles from the Wealden; many of such magnitude, that the assemblage resembled an accumulation of the dissevered skeletons of gigantic elephants or mastodons.

not a vestige of any of the mammalia occurs in the Wealden deposits. Even these teeth, which so strikingly resemble the incisors of the Rhinoceros, and these bones of the feet and toes, which are so similar in shape and size to those of the Hippopotamus, belong to oviparous quadrupeds. Many of the specimens can be referred to certain extinct forms of saurians, or lizards ; but the affinities of others have not been ascertained. The determination of these fossil bones is indeed no easy task ; for while in many marine deposits, considerable portions of the skeletons, or even the entire series, are often discovered, in the Wealden, with but few exceptions, every bone, tooth, and scale, has been found apart from each other ; and as if to render the task still more perplexing, the relics of several different species and genera are scattered at random through the rocks. Every specimen, too, bears evidence of having been transported from a distance. It would seem as if the limbs and carcasses of the animals had floated down the stream, and been rolled backwards and forwards by the tides, and the bones broken, before they sank down and became imbedded in the mud of the delta. To collect these scattered fragments, and extricate them from the solid rock —to reunite them into a whole, and assign to each skeleton of the respective animals, the bones which once belonged to it, yet not to confound the different species together—such is the labour which the comparative anatomist has to perform, who undertakes to investigate the nature of the wealden saurians. I reserve for the next Lecture some general observations on the economy and habits of reptiles, and will now describe the fossil relics before us.

30. Turtles of the Wealden.—The bones and plates of chelonian reptiles are very common in the Purbeck limestone, and in the grit, sandstone, and shale of Tilgate Forest. They are referable to two or more freshwater, and one marine species ; one of the former appears to belong

to an *Emys*, or freshwater turtle, described by Cuvier,* as occurring in the Jura limestone at Soleure. It is a very flat species, and probably attained two feet in length.

Many ribs and other parts of the carapace of a *Trionyx* have been discovered in the shale of Pounceford, and grit of Tilgate Forest; the external surface of the dorsal plates is shagreened all over, as is usual in these chelonians, which have no shelly covering, but only a thick, tough skin, or integument; the recent species inhabit the Nile and Euphrates.

Trionyx Bakewelli. Among these remains of fresh-water turtles are costal and dorsal plates, and other bones of a chelonian reptile, which, in its essential characters, is closely allied to the *Trionyces*, but differs from all known recent species, in having possessed a horny dermal integument formed of plates of tortoise-shell. This is indicated by the fossil ribs, which not only have a shagreen or punctated surface, like those of the recent species, but also imprints of the horny scutes or scales.† Except in having a defensive coating of tortoise-shell, this turtle must have closely resembled the existing predaceous, soft, fresh-water chelonians; and doubtless, like those reptiles, inhabited the muddy beds of rivers and lakes; preying upon the eggs and young of the larger reptiles, and on the mussels and other fluviatile mollusca, whose shells are commonly associated with its remains.‡

Chelonia Bellii. A considerable portion of the carapace

* Oss. Foss. tom. v. p. 232.

† See Medals of Creation, vol. ii. p. 777.

‡ I discovered remains of this species, and pointed out their peculiar characters, more than twenty-five years since. The specific name is to commemorate the important services rendered to British Geology by my late respected friend, Robert Bakewell, Esq., author of the best "*Introduction to Geology,*" in this or any other language. See my Fossils of Tilgate Forest, p. 60, Pl. VI. *fig.* 1; and Geology of the South-East of England, p. 225.

and plastron of a true marine turtle, belonging to a species three feet in length, was obtained from the sandstone of Tilgate Forest many years since, and some fragments are figured in my early works on the fossils of that district.*

31. MARINE REPTILES OF THE WEALDEN.—By far the greater part of the bones obtained from the quarries of Tilgate Forest, Horsham, &c. belong to colossal terrestrial reptiles; but with these are associated the osseous remains of two or three genera, which there is every reason to suppose were inhabitants of the sea into which the river flowed, that deposited the strata of the Wealden.

Plesiosaurus. I have collected from various Sussex localities, bones of the extremities and cervical and caudal vertebræ, of one or more species of the extraordinary marine reptile called *Plesiosaurus*, whose remains are found in such prodigious quantities in the Lias and Oolite;† thus, we have proof that this animal was at least an occasional visitant of the bays and estuaries of the Wealden river.

Cetiosaurus.‡ Some of the largest vertebræ and bones found in the Wealden strata belong to an aquatic reptile, probably of marine habits, of which numerous bones occur in the oolite of Oxfordshire, Northamptonshire, &c. The vertebræ are distinguished by their nearly circular faces, and relatively short bodies; in the dorsal the anterior face is nearly flat, and the posterior concave; but in the caudal both are concave, with a well-defined border, which gives the body a deeply excavated character. Some specimens

* Medals of Creation, vol. ii. p. 776. Fossils of Tilgate Forest, Pl. VII. fig. 2.

† Fossils of Tilgate Forest, Pl. IX. figs. 4, 5.

‡ The name implies the affinity of these reptiles to the cetaceans. See Medals of Creation, vol. ii. p. 726. No vestiges of true cetaceans have been found in a fossil state in strata older than the tertiary it would seem that the advent of the terrestrial and aquatic mammalia on our globe, took place contemporaneously.

are eight inches in the transverse diameter of the articular face, and but four and a half in the antero-posterior length of the body of the vertebræ.*

These reptiles must have rivalled the living Whales in bulk, for some specimens indicate a length of forty or fifty feet; they are supposed to have had web-feet, and a broad vertical tail.† The bones found in the Wealden may have been transported from the sea by the tide, or the living animals may have occasionally been carried far up the river, as is sometimes the case with the modern cetaceans.

32. Crocodilian reptiles of the Wealden.‡—The loricated or mailed saurian reptiles, as the Alligators, Crocodiles, and Gavials, of which numerous remains occur in the eocene strata, are well known as the largest existing forms of oviparous quadrupeds.

No relics of any living species have been observed in the secondary strata, but several allied genera appear to have flourished during these epochs. But the crocodilians of these ancient types differed materially in structure from the modern; and particularly in the vertebral column, which in one fossil genus only is composed of concavo-convex vertebræ, and these are in a reversed position; the ball or convexity of the bone being directed forwards, or anteriorly, instead of in the contrary direction, or posteriorly, as is the case in the living Crocodiles.

As a general character, it may be stated that the crocodilians with broad muzzles, as the Cayman and Alligator, do not occur in a fossil state below the eocene deposits; all the reptilian remains of that family in the secondary forma-

* I discovered a fine suite of four consecutive vertebræ in the sandstone of Tilgate Forest, and succeeded in extricating them entire from the rock. One of these vertebræ is figured in Philos. Trans. for 1841, Pl. IX. fig. 13.

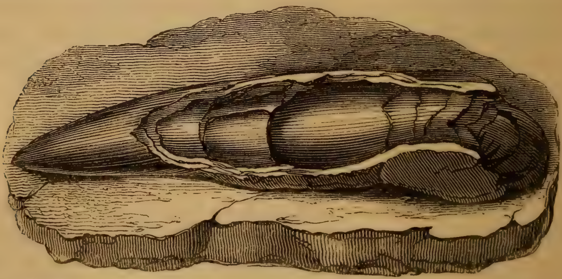
† British Association Reports, 1841, p. 102.

‡ Medals of Creation, p. 718.

tions, belong to the division with elongated beaks or muzzles, like the Gavial of the Ganges.

*Streptospondylus.** The bones, and jaws with teeth, of the crocodilian reptiles to which this name (signifying *reversed spine*) has been applied, were first discovered in the Oolitic clays of Honfleur and Havre ; the vertebræ are united by a ball and socket joint ; the convexity or ball being anterior, instead of posterior as in the living crocodiles. Several large vertebræ of these reptiles have been obtained from the sandstone and grit of Tilgate Forest, and from the clays in Brook Bay, in the Isle of Wight.

33. FOSSIL TEETH OF CROCODILIAN REPTILES.—The teeth of the Crocodile are very numerous ; they are of a conical form, and consist of a succession of cones, like a series of thimbles, of various sizes, fitted into each other ; they are striated externally, and have a prominent lateral ridge ; as the outer tooth wears away, a new one is ready to supply its place ; the teeth of the old Crocodile are



LIGN. 100.—TOOTH OF CROCODILIAN REPTILE: FROM TILGATE FOREST; *natural size.*

(Goniopholis crassidens.)

therefore as fresh as those of the young animal but just escaped from the egg. The interior of the teeth is never

* Medals of Creation, vol. ii. p. 725.

completely filled up; hence, at whatever age a tooth may be removed, there is found, either in the socket, or in the cavity of the tooth itself, a new germ, in a greater or less state of advancement, ready to occupy the place of the old one, when the latter shall be removed; and this succession is often repeated. In this fossil tooth (*Lign.* 100) from Tilgate Forest, the internal series of cones is exposed, in consequence of the removal of the outer case of the old tooth. Numerous fossil teeth, possessing this character, have been obtained from the wealden; they are separable into two kinds.

The first is from an inch to two inches in length, of a slender acuminated form, laterally compressed, and gently recurved, with a thin edge in front and behind; resembling in appearance a tooth of the Megalosaurus (*Lign.* 101), with the serrated edges worn off.* Some biconcave vertebræ, with compressed wedge-shaped centres,† are supposed to belong to the same reptile, which has been named *Suchosaurus cultridens.*‡ The other form of tooth has a cylindrical base, and an obtusely conical crown with numerous longitudinal grooves and ridges, and a sharp line on each side; a specimen, attached to a small block of sandstone, is represented *Lign.* 100.§

34. Swanage fossil crocodile.—The teeth last described are comparatively of frequent occurrence in the wealden of the south-east of England, and are often associated with dermal, or skin-bones, which are the osseous supports of the thick horny scutes or scales of the integument of mail, with which the Gavials and other

* Medals of Creation, vol. i. Pl. VI. *fig.* 7. Fossils of Tilgate Forest, Pl. V. *fig.* 10.

† Fossils of Tilgate Forest, Pl. IX. *fig.* 11.

‡ British Association Reports for 1841, p. 68.

§ Medals of Creation, vol. i. Pl. VI. *fig.* 5. Fossils of Tilgate Forest, Pl. V. *figs.* 1, 2, 9.

crocodilians are covered;* and certain extinct reptiles appear to have had these scutes even more largely developed. As the fossil teeth and dermal bones were commonly associated together, I was led to suppose that they might belong to the same species; an opinion which was confirmed a few years since, by the discovery, in the Isle of Purbeck, of a considerable portion of the skeleton of a Crocodile, with similar teeth and dermal appendages.

In the summer of 1837, the workmen employed in a quarry in the immediate vicinity of Swanage, had occasion to split asunder a large block of the Purbeck limestone, when, to their surprise, they perceived many bones and teeth on the surfaces they had just exposed. As this was no ordinary occurrence—for though scales of fishes, shells, &c. were frequently observed in the stone, bones had never before been noticed—both slabs were carefully preserved by the proprietor of the quarry; and fortunately my intelligent friend, Robert Trotter, Esq. happening to visit Swanage a short time afterwards, heard of the discovery, and with that liberality and ardour for the advancement of science for which he is distinguished, obtained the specimens, and presented them to me. I cleared away the stone, so far as the brittle state of the bones would permit without injury, and they are now two of the most interesting groups of crocodilian remains that have been discovered in this country.†

On one of the slabs, a considerable portion of the left side

* See Medals of Creation, vol. ii. p. 701.

† Both the slabs of the Swanage specimen are now placed side by side in a case in the British Museum; in the same room with the remains of the Iguanodon and other fossil saurians. There can be no doubt that the entire lower jaw of this reptile might have been obtained, if the quarrymen had taken the precaution of examining the adjoining block of stone. In the same case are several teeth and dermal bones of this species from Tilgate Forest.

of the lower jaw, with two teeth in place, is preserved; and many detached teeth and dermal bones are distributed over the stone. There are numerous ribs and biconcave vertebræ, the latter having an irregular medullary cavity in the centre of the body; the chevron bones are of the same form as in the Gavial. The bones of the pelvic arch, and several of those belonging to the extremities, remain.

The dermal scutes are flat; their width, which is equal throughout, is about one-third of the length. They are of various sizes, from three to six inches long. The inner surface is smooth, and the external covered with irregular deep pits or hollows; some round, others angular. These differ from all known recent and fossil dermal bones, in having a lateral projection which fits into a corresponding depression on the under surface of the opposite angle of the adjoining scute.* Numerous hexagonal and pentagonal scutes, articulated together by marginal sutures, also entered into the composition of the osseous dermal cuirass; this reptile must, therefore, have possessed a flexible and impenetrable coat of mail, capable of affording protection against the attack of any assailant.†

Macrorhyncus Myeri. The cranium of another reptile of the Gavial type, has been found in the wealden of Germany, and is figured in Dr. Dunker's beautiful work; it is characterized, as the name implies, by its extremely elongated snout.‡

Poecilopleuron. Vertebræ and other bones of a crocodilian reptile, related to the *Goniopholis*, are occasionally found in the wealden deposits of Tilgate Forest and the Isle of Wight, associated with the remains of that

* Medals of Creation, vol. ii. p. 702.

† Teeth of the Swanage Crocodile or *Goniopholis* have been found in the wealden of Germany, by Dr. Dunker; see Mon. Nord. Weald. Pl. XX. *fig*. C.

‡ Mon. Nord. Weald. Tab. XX.

animal. The vertebræ are biconcave, and have a large medullary cavity in the middle of the centrum of the bone, which is often filled up with white calcareous spar. The body of the vertebra is contracted in the middle, the neural arch anchylosed with no trace of suture, and the spinous process is remarkable for its backward inclination.*

Raphiosaurus? Professor Owen states, in his report on the British fossil reptiles, that no vertebræ of the true crocodilian type, that is, with the anterior surface concave, and the posterior face convex, have been found in strata below the chalk. I have, however, discovered in the sandstone of Tilgate Forest, several small vertebræ of this kind, which closely resemble in their proportions those of the small lizard of the chalk, the *Rhaphiosaurus* (*ante*, p. 354).†

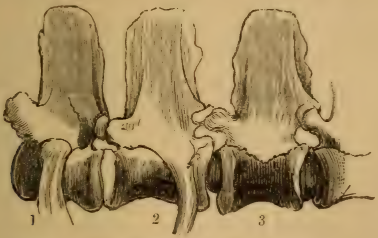
* The remains of this reptile were first described by M. Deslongchamps, (under the name of *Poecilopleuron*,) from specimens discovered in the Oolite near Calne, in Normandy. See British Association Report for 1841, p. 84; Fossils of Tilgate Forest, Pl. IX. *fig.* 8, represents a caudal vertebra.

† *On a peculiarity of structure in the first caudal vertebra of the adult Gavial.* — The discovery of the Swanage crocodile induced me to institute a rigorous examination of the skeletons of the recent Gavials in the museum of my friend Dr. Grant, of the London University, with the view of determining the affinities of the fossil remains. In the course of my investigation I detected a peculiar conformation in the *first caudal* or *coccygeal* vertebra of the recent gavial, which, strange to say, appears to have escaped the notice of previous observers. The vertebræ of the existing crocodilian family are invariably concave in front, and convex behind; but the *first caudal* (*Lign.* 100,* 3) in the adult Gavial is *doubly convex;* and the last sacral vertebra (2) *concave posteriorly,* to receive the anterior convexity or ball of the caudal. These peculiarities are shown in the annexed sketch.

The last *cervical* vertebra in Turtles and Tortoises has a similar structure. In a very young Gavial in Dr. Grant's collection, the sacro-coccygeal surfaces are as flat as in the vertebræ of mammalia; while in the Crocodile and Alligator, of the same early period, the coccygeal vertebra is convex in front, as in the adult gavial. This mechanism

35. Dinosaurians.*—We now arrive at the consideration of three genera of extinct saurians or lizards, the Megalosaurus, Iguanodon, and Hylæosaurus, which are so essentially different in their osteological characters from all other known types, as to constitute a distinct order, that unites the lacertian with the crocodilian oviparous quadrupeds. The remains of these animals are principally distributed in the Wealden deposits; but of the first, the most interesting relics have been obtained from the Stonesfield slate, which is situated in the lower division of the Oolite; and of the

confers the power of free motion without risk of dislocation or mutilation. The importance of a knowledge of this fact to the palæontologist is too obvious to require remark; the discovery in the wealden of a caudal vertebra, having both the extremities convex, would, I must confess, have been very perplexing, previously to my detection of this peculiarity of structure in the recent Gavial.



Lign. 100.*—Sacral and caudal vertebræ of the gavial.

Figs. 1. 2. The two anchylosed sacral vertebræ. 3. The first caudal or coccygeal vertebra, which is doubly convex.

* *Dinosaurians*, signifying *fearfully great Lizards;* a term employed by Professor Owen to designate an order of extinct terrestrial reptiles, which comprises the Iguanodon, Megalosaurus, and Hylæosaurus. It is to be regretted that some other name was not chosen; for the occurrence of the same word (δεινὸς, *deinos*) in Dinotherium (*ante*, p. 173), Dinornis (*ante*, p. 129), &c. suggests to the unscientific reader, an erroneous idea of an affinity between these extinct reptiles, mammals, and birds, which it was desirable to avoid.

second, a considerable portion of the skeleton has been found in the greensand of the chalk formation.*

These genera comprehend the colossal crocodile-lizards of the dry land of the secondary epochs. The long bones of the extremities of the two first are of colossal proportions, and have large medullary cavities, with well developed processes; their metacarpal, metatarsal and digital bones, with the exception of the ungueal phalanges, (bones which support the nails or claws,) resemble those of the Hippopotamus, and other large pachydermal mammalia.† A very remarkable peculiarity in the osteological characters of this order consists in the sacrum being made up of five vertebræ, anchylosed together into a solid column; whereas in all other saurians, it is formed of but two united vertebræ; and this is accompanied by another modification, for the neural arches of the vertebræ are shifted to the interspaces between the bodies of those bones, and thus great solidity is given to the pelvic arch. Both these arrangements have an evident relation to the great size of the hinder extremities of these reptiles, and the enormous carcass they had to support.

From the great magnitude of some of the bones, these fossils have excited the curiosity even of the common observer; and although an exaggerated idea has been generally entertained of the size of the original animals, yet even when their assumed proportions are reduced to their natural dimensions by the rigorous formulæ of the comparative anatomist, they are sufficiently colossal to satisfy the most enthusiastic lover of the marvellous. Of this the reader may be easily convinced, if he will visit the

* See Medals of Creation, vol. ii. p. 729.

† See Medals of Creation, chap. xviii. for a concise view of the osteological characters of these reptiles: and Professor Owen's Report on Fossil Reptiles in the Transactions of the British Association of Science, for 1841, for a full consideration of the subject.

British Museum, and after examining the largest thigh-bones and leg-bones of the Iguanodon, repair to the zoological gallery, and inspect the stuffed specimens of the existing species of Crocodiles, and Alligators ; then let him imagine the fossil bones to be clothed with appropriate muscles and integuments, and consider the enormous trunk which limbs of such bulk must have been designed to support ; and he will obtain some idea of the appalling magnitude of those

> " Mighty Pre-Adamites that walked the earth
> Of which ours is the wreck."—Byron.

36. The Megalosaurus.*—The fissile oolitic shale of Stonesfield in Oxfordshire, of which I shall have occasion to treat more particularly in the next Lecture, has long been celebrated for its fossil remains ; among which the teeth and bones of a very large unknown animal, claimed particular attention.

Lign. 101.—Tooth of a young Megalosaurus : *from Tilgate Forest*; (*nat. size*).

The Rev. Dr. Buckland first pointed out the true character of these remains, and showed that they belonged to an extinct carnivorous reptile of enormous magnitude ; which he distinguished by the name of *Megalosaurus*, or Gigantic-Lizard.† Numerous teeth, vertebræ, and other bones of this reptile, were among the earliest discoveries in the wealden deposits of Tilgate Forest ; and several specimens are figured in my works on the geology of that interesting district.‡ The specimens from the wealden consist of teeth, dorsal and caudal vertebræ, thigh-bones, and other bones of the extremities ; they belong

* Medals of Creation, vol. ii. p. 732.
† Geol. Trans. vol. i. *second series.*
‡ Fossils of Tilgate Forest, Pl. IX. p. 67.

apparently to the same species (*M. Bucklandi*) as that of Stonesfield. The tooth of this reptile (*Lign.* 101) is distinguishable by its sabre-like form, conical laterally compressed crown, and finely serrated trenchant edges. From this structure of the tooth it may be inferred that the Megalosaurus was carnivorous ; its length is estimated at nearly thirty feet.

37. The Iguanodon.*—Soon after my first discovery of remains of large vertebrated animals in the strata of Tilgate Forest, some teeth of a very remarkable character particularly engaged my attention, from their dissimilarity to any that had previously come under my notice. Even the quarrymen, who had been accustomed to collect the teeth of fishes and other relics of that nature, had not observed them, until shown three or four mutilated specimens, which I had extricated from a block of stone on the road-side. Attention having thus been directed to the subject, additional examples were soon discovered ; and at length I obtained a series of teeth in various conditions, from the pointed unused tooth of the young reptile (*Lign.* 102, *fig.* 2), to the obtuse, worn, flat crown of the adult (*Lign.* 104). From the resemblance in the form of the perfect tooth to that of the Iguana,† a terrestrial lizard of

* Medals of Creation, vol. ii. p. 739. Brit. Assoc. Reports for 1841, p. 120.

† The Iguanas are land lizards, which inhabit many parts of America and the West Indies, and are rarely met with north or south of the tropics. They are from three to five feet in length, and feed on insects and vegetables, climbing trees, and chipping off the tender shoots. They nestle in the hollows of rocks, and deposit their eggs, which are like those of turtles, in the sands or banks of rivers. The Iguana is furnished with a row of very small, closely-set, pointed teeth, with serrated edges, which have no distinct alveoli or sockets, but are attached at the base, and by the outer surfaces of the fangs to the jaw; the alveolar process forms an external parapet, but there is no internal bony covering. The new teeth do not, as in the croco-

the West Indies, I proposed the name of *Iguanodon* (signifying an animal with teeth like the Iguana), for the extinct reptile to which they belonged.*

The numerous bones and teeth subsequently exhumed from the strata of Tilgate Forest, Horsham, Battle, Hastings, and other places in Sussex, and in the Isle of Wight ;† and of a considerable portion of the skeleton of an individual discovered in the greensand of Kent, have supplied the data upon which our present knowledge of the characters of the original is based. But unfortunately the form and structure of the skull are still unknown ; and of the jaws, a fragment retaining the fangs of a few teeth, is the only recognizable relic.

38. Teeth of the Iguanodon.‡—The first specimen which arrested my attention was a portion of a large tooth which, from the flat surface of the crown, had evidently belonged to a herbivorous animal ; for it possessed the prismatic form of a worn incisor of one of the large pachy-

dile, spring up in the centre of the cavities of the old, and push through them, but arise from near the inner part of the base, and by pressure occasion the absorption of a portion of the fang of the old tooth, which they ultimately displace, by destroying the adhesion to the dental parapet. The teeth of the Iguana closely resemble the perfect fossil tooth, (*Lign.* 102, *fig.* 2,) in form, but not in structure or size ; those of the recent lizard scarcely exceeding in magnitude the teeth of the common mouse. In the Iguana the crown of the tooth never presents a flat surface ; it is broken or chipped off by use, but not ground smooth as in the herbivora. The reason is obvious ; none of the existing reptiles are furnished with cheeks or moveable coverings to their jaws, and therefore cannot perform mastication ; their food or prey is seized by the teeth and tongue, and swallowed whole.

* See my memoir "On the teeth of the Iguanodon, a newly discovered fossil herbivorous reptile, from the strata of Tilgate Forest." Philos. Trans. for 1825.

† Geology of the Isle of Wight, p. 312.

‡ Medals of Creation, vol. ii. p. 742.

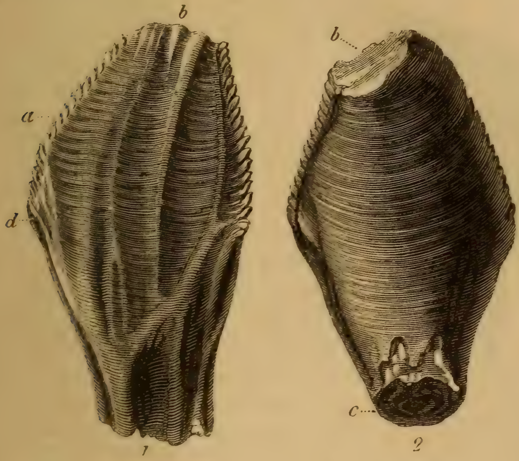
derms.* The enamel was thick in front and thin behind, by which arrangement a sharp cutting edge must have been maintained in every stage of use. There was no fang, but

LIGN. 102.—TEETH OF THE IGUANODON: FROM TILGATE FOREST.

Fig. 1. The inner, and 3, the outer, aspect of a tooth worn flat, and the fang absorbed.
2. Tooth of a young animal.
4. Outer, and 5, inner, surface of a tooth of an adult.
6. Lateral view of the serrated edge of fig. 5, magnified.
a, The surface worn by mastication.
c, The indentation produced by the pressure of the new tooth.

* This specimen was submitted to the examination of Baron Cuvier by my friend Mr. Lyell, at that time in Paris; and M. Cuvier pronounced it to be an upper incisor of a rhinoceros; and it was not till I had collected an entire series of teeth in various states of detrition, that the correctness of my opinion was admitted, either as to the nature of the fossil, or the geological position of the stratum in which it was found. See Ossemens Fossiles, tom. v. p. 351.

the base was *indented*, not broken off; proving that the shank had been removed by absorption from the pressure of a new tooth, which had grown up, and caused the old one to be thrown off.



LIGN. 103.—TOOTH OF THE IGUANODON: FROM TILGATE FOREST. *(nat. size.)*

Fig. 1. Front aspect, showing the longitudinal ridges, and denticulated margins of the crown: *a*, the denticulated margin; *b*, apex of the crown partly worn by use; *c*, transverse fracture of the fang, exposing a section of the medullary cavity occupied by the ossified remains of the pulp; *d*, the base of the denticulated border.

Fig. 2. The inner aspect of the same.

In the series of teeth before us (*Ligns.* 102, 103, 104), we may trace every gradation of this change; from the pointed, angular, perfect crown and fang (*Lign.* 102, *fig.* 2), and the partially worn specimen (*figs.* 4, 5), to the mere stump (*figs.* 1, 3): in which the summit is ground flat, and the shank entirely absorbed from the pressure of a successional tooth. The perfect teeth of the Iguanodon are distinguished by their prismatic form; the presence of from two to four or five ridges, which extend down the front; and the denticulated lateral margins of the crown (*Lign.* 102, *fig.* 6). The latter appear as simple serrations in the figure, *Lign.* 103,*a*; but when viewed laterally (*Lign.* 102, *fig.* 6), are found to consist of denticulated plates.

The deciduous tooth of an adult Iguanodon, with the crown flat, and the fang absorbed, is well exemplified in this specimen (*Lign.* 104) from the Isle of Wight; in which the crown is worn down almost to the neck; the series of denticulated plates having entirely disappeared. In this respect the Iguanodon differs from all known living or extinct lizards; for all other herbivorous reptiles chip off and swallow their food whole; the construction of their jaws not admitting of a grinding motion. It is therefore obvious, not only that the Iguanodon fed on vegetables, but that it was capable of masticating its food like the horse and other herbivorous mammalia: while the absorption of the fang shows that a constant succession of teeth took place at all periods of the animal's existence, as is the case in many other reptiles. The tooth, when examined microscopically, exhibits a corresponding internal structure; the tooth-ivory or dentine being of a softer and coarser texture than in other reptiles, and resembling that of the great vegetable feeders of the sloth tribe (*ante*, p. 167).* These dental instruments must therefore have been admirably adapted, in every stage, for the laceration and comminution of the tough vegetable substances, which there can be no doubt constituted the chief food of this colossal quadruped.

Lign. 104.—Tooth of an Iguanodon; *from Brook Bay, Isle of Wight.* (*Nat. size.*)

A portion of the lower jaw of a young Iguanodon, with the fangs of fifteen teeth, closely and evenly set, in a regular series, and imbedded laterally in grooves of the dentary bone, and with germs of successional teeth at the base of the old one, indicate a close analogy to the arrangement of the teeth in the recent Iguana, but with this difference, that in the living kind there are no sockets; the teeth being attached laterally to a parapet of the dental bone; while, in the Iguanodon, the smooth surface and pointed termination of some of the fangs, indicate an implantation in distinct alveoli.†

* Medals of Creation, vol. i. Pl. VI. *fig.* 4.

† Philosophical Transactions for 1841. Pl. V. *fig.* 1; and Pl. VII. *figs.* 1, 2; p. 131.

39. The Maidstone Iguanodon. *Plate* III.—From the gigantic size of the fossil teeth, as compared with those of recent lizards, I was led to conclude that many of the colossal bones, collected from time to time in Tilgate Forest, belonged to the same kind of reptile; and by comparing the bones with those of an Iguana, (presented to me by Baron Cuvier,) I at length succeeded in determining many parts of the skeleton, and was enabled to restore, as it were, the form of the Iguanodon, and ascertain its proportions:* the correctness of my deductions was shortly to be put to the test, by a discovery in a neighbouring county.

In May, 1834, some workmen employed in a stone-quarry, in the occupation of Mr. W. H. Bensted, of Maidstone, observed in a mass of rock which they had blasted, several portions of what they supposed to be petrified wood; they preserved the largest piece for the inspection of the proprietor of the quarry, who, perceiving that it was a portion of bone belonging to some gigantic animal, gave directions that every fragment should be collected, and succeeded in obtaining those pieces, which, when united and completely developed, formed the highly interesting fossil here delineated, (*Pl.* III.)†.

* In stating that there was a general resemblance between the teeth and bones of the Iguanodon and those of the Iguana, it was never intended to affirm, that any close analogy existed; still less to assert, as some writers have supposed, that the living Iguana is a miniature representative of the colossal reptile of the wealden.

† The rock was shattered to fragments by the explosion, and the bones were broken into a thousand pieces: but after much labour I succeeded in uniting the several blocks of stone, and ultimately cleared and repaired the bones, and restored the specimen to its present state. It is placed under a large glass frame, in the palæontological gallery of the British Museum. The circular hole seen near the centre of the fossil, was made to introduce the charge of powder for blasting the rock.

This specimen consists of a considerable number of the bones of the inferior portion of the skeleton of an adult, but not aged, individual. The bones are imbedded in the stone in a very confused manner ; few of them lying in their natural order of juxtaposition, and all being more or less flattened and distorted. The following are the most important, and the best preserved ; but there are numerous fragments, too imperfect to admit of determination.

Two *thigh-bones,* each 33 inches long. *Plate* III. *figs.* 1, 2.

One *leg-bone* (*tibia*), 30 inches long. *Fig.* 3.

Metatarsal and *phalangeal* bones of the hind feet; these much resemble the corresponding bones of the hippopotamus. *Figs.* 4, 4, 4.

A *claw-bone* (*ungueal bone*), which was originally covered by a horny investment; it resembles the corresponding bone of a land tortoise. *Fig.* 5.

Two *metacarpal* bones of the fore feet, each 14 inches in length. *Fig.* 6.

A *radius,* or bone of the fore-arm. *Fig.* 7.

Several *dorsal* and *caudal vertebræ* (bones of the spine and tail). *Figs.* 8, 8, 8.

Fragments of several ribs. *Figs.* 9, 9, 9.

Two *clavicles,* or collar bones, each 28 inches in length, resembling the bone figured *Plate* IV. *figs.* 1, 2; Geology of the South-East of England. These bones are of a very singular form, and differ essentially from any known clavicle. *Figs.* 10, 10.

Two large flat hatchet-shaped bones, which belong to the pelvis (*iliac bones*). *Figs.* 11, 11.

A *chevron-bone,* or inferior spinous process of a vertebra of the tail *Fig.* 12.

A portion of a tooth, and the impression of another.—The preservation of these relics was most fortunate, as the identity of the animal with the *Iguanodon* of Tilgate Forest is thereby completely established.

The geological position of this specimen forms an exception to what has been previously remarked of the remains of the Iguanodon from the Wealden ; for while in the latter the bones are associated with terrestrial and fluviatile exuviæ only, the Maidstone fossil was imbedded in a marine deposit.* This discrepancy, however, does not affect the arguments previously advanced, as to the fluviatile origin of the strata of the Wealden ; it merely shows that part of the delta had subsided, and was covered by the chalk ocean, whilst the country of the Iguanodon was still in existence ; and that the body of one of these reptiles was drifted far out to sea, and sunk down in the depths of the ocean : in like manner, as at the present day, bones of land quadrupeds may not only be engulfed in the deltas of rivers, but also in marine deposits far from land.

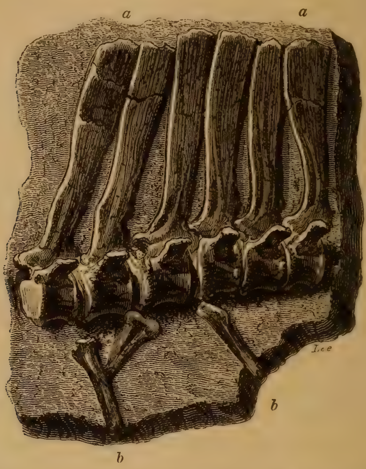
This specimen proves that the separate bones found in the strata of Tilgate Forest, and which I had assigned to the Iguanodon, solely from analogy, have been correctly appropriated.

40. Vertebræ of the Iguanodon.—The peculiarities in the vertebral column of the Iguanodon are pointed out in the Medals of Creation,† and anatomical details would here be irrelevant ; a few particulars must, however, be noticed. The transverse processes of the dorsal and lumbar vertebræ are very long and straight, indicating a considerable expanse of the abdominal cavity, suitable for the capacious viscera of a herbivorous quadruped. In the caudal vertebræ, both the spinous processes (*Lign.* 105, *a*, *a*.) and

* The stone in which the bones are imbedded is of that hard variety of the grey, arenaceous limestone, called *Kentish rag*, which is much employed in various parts of Kent, and in the west of Sussex, for building, and for repairing the roads. It abounds in the marine shells which are characteristic of that division of the chalk formation. In the quarry in which the remains of the Iguanodon were found, there have been discovered wood perforated by *lithodomi*, or boring shells ; impressions of leaves and stems of trees, with *trigoniæ*, *ammonites*, *nautili*, &c. ; conical striated teeth of the marine reptile called Polyptychodon (*ante*, p. 354), some of which are two inches in diameter at the base ; scales and teeth of squaloid fishes, and maxillary bones of the Chimæra or Endaphodon of Sir P. M. Egerton. Molluskite abounds in these strata.

† Vol. ii. p. 745.

the *chevron bones*, (*b, b*,) are of great length; the latter have their bases so blended as to form but one face for articulation with the truncated inferior angles of the body



Lign. 105.—Six caudal vertebræ of an Iguanodon; from Tilgate Forest.

(One-sixteenth natural size.)

a, a, Spinous processes, fifteen inches high. *b, b, Chevron bones*, imbedded in the stone near their original articulation between two of the vertebræ.

of the vertebræ, leaving a vertical and elongated channel, for the passage of the large blood vessels of the tail. The proportions of these elements of the caudal vertebræ indicate a great vertical development of the tail. In the beautiful specimen before us (*Lign.* 105) of six united caudal vertebræ, imbedded in a block of Tilgate grit, with both the upper and inferior spinous processes displayed, these characters are strikingly obvious. The width, or rather height, of that portion of the tail to which these bones belonged, must have been at least twenty-seven inches.

Horn of the Iguanodon. The Iguanas are distinguished among the lacertian reptiles, for their exuberant dermal appendages. Some have serrated processes or spines on the back; others on the tail; while many have conical warts or horny protuberances on the head and snout, of which the *Iguana cornuta* is a remarkable example.* A fossil possessing the form and structure of these nasal tubercles, was found, many years since, in the grit of Tilgate Forest;† another specimen, about one-third the size, has also been discovered. It is composed of bone, and has that singular disposition of the osseous fibres that prevails in the dermal bones of certain reptiles. Its surface shows the impressions of the vessels of the integument by which it was originally covered. It is four inches high; and the base, which is of an irregular elliptical form, is 3.2 inches by 2.1.

LIGN. 106.—HORN OF THE IGUANODON; *from Tilgate Forest.*

(*One-third natural size.*)

Though there is no evidence to prove that this process belonged to the Iguanodon, there can be no doubt of its being a horn, or nasal tubercle, of one of the large reptiles with whose bones it was found collocated. It may possibly be referable to the Hylæosaurus, in which the dermal appendages appear to have been enormously developed; but in the absence of all proof, and from the close resemblance which the fossil bears to the horn on the snout of the Iguana cornuta, we would provisionally refer it to the Iguanodon.

41. FEMUR, &c. OF THE IGUANODON.—Several specimens of the femur or thigh-bone, of the bones of the hind legs, and of the metatarsal, phalangeal, and ungueal bones, have

* See Philos. Trans. for 1841, Pl. IX. *fig.* 3.

† It is figured in Fossils of Tilgate Forest, Pl. XX. *fig.* 8.

been obtained from various localities of the Wealden. The first fragment of a thigh-bone that came under my notice, was a portion of the middle part of the shaft, which is of a quadrangular form ; and this was so large, shapeless, and unintelligible, that many years elapsed before I obtained any clue as to its real nature.* The toe-bones presented so little correspondence with those of reptiles, and such a similitude to the metatarsals of the large pachyderms, as for example those of the Hippopotamus, that it was long ere their true affinities could be determined.†

To convey an idea of the enormous size which some individuals must have attained, I may state that one perfect thigh-bone is three feet eight inches long, and thirty-five inches in circumference at the condyles, and that some fragments indicate a greater magnitude. A leg-bone or tibia, of which I have a large portion, must have been four feet long ; the corresponding thigh-bone would be a foot longer ; the entire length of the limb must therefore have exceeded nine feet ! These bones occur of very different sizes ; I have a femur only five inches long, and other bones, that must have belonged to very young reptiles.

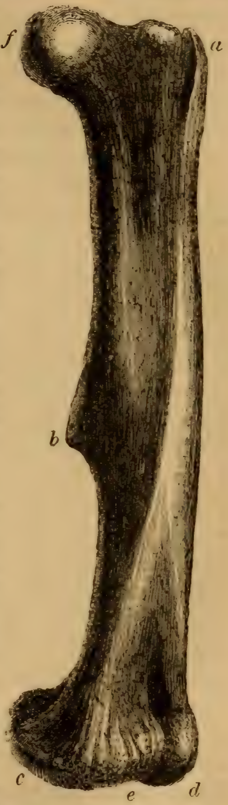
The femur of the Iguanodon is remarkable from the combination of mammalian characters which it presents, in its well-marked head and neck, trochanters, condyles, and medullary cavity. The head (*Lign.* 107, *f*,) is hemispherical, and projects inwards; and a laterally flattened process or trochanter (*a*) forms an external buttress or boundary of the neck of the bone, from which it is separated by a deep, narrow, vertical fissure. The shaft of the bone is subquadrangular; a slightly elevated ridge, produced by the union of two broad, flat, longitudinal surfaces, indicating the attachment of powerful

---

* This fragment is figured in Foss. Tilg. Forest, Pl. XVIII.

† Baron Cuvier, with that noble candour for which he was as eminently distinguished as for his transcendent genius, wrote to me as follows :—" Les fragmens d'os du métacarpe ou du métatarse, sont si gros, qu'au premier coup d'œil je les avais pris pour ceux d'un grand Hippopotame."

muscles, extends down the middle of the anterior face, and diverging towards the inner condyle, gradually disappears. The shaft terminates below in two large, rounded, and laterally-compressed condyles (*c*, *d*), which are separated in front and behind by a deep groove (*e*). Near the middle of the shaft, the mesial, or inner edge, forms a compressed ridge, which expands into an angular projection, or trochanter (*b*). Thus the upper part of the femur may be known by the presence of the upper trochanter (*a*); and if that process is broken away, the fractured surface indicating its position will be detected. If a fragment of the middle part of the shaft only is found, the flattened angular spaces, and the submedian trochanter (*b*), or the mark of its attachment, will identify it. The lower extremity of the femur may be distinguished by the deep groove (*e*) between the condyles, both in front and behind. The medullary cavity is very large.



Lign. 107.—Left femur of an Iguanodon. *From Brook Bay.*

(*The original*, 40 *inches in length.*)

a, Upper trochanter.
b, Middle trochanter.
c, Inner, *d*, outer condyle.
e, Groove between the condyles.

42. Probable form and size of the Iguanodon.—From numerous detached bones that have been collected from various localities of the Wealden, and with the aid of the few specimens in which several are collocated in the same block of stone, the size and proportions of the body and limbs of the Iguanodon have been determined; yet but a vague idea of the form and appearance of the original animal can be derived from the relics hitherto discovered. For the great discrepancy between the known parts of the skeleton, and the corresponding bones in the

largest existing saurians, renders it vain to attempt the restoration of the form of this colossal reptile, till the skull, jaws, &c. are known. In all probability the entire or a considerable portion of the skeleton of a young Iguanodon, will sooner or later be brought to light, and yield the information necessary to enable the palæontologist to reconstruct the skeleton, and delineate the physiognomy of the living original.

In the present state of our knowledge we may, however, safely infer, that the body of the Iguanodon was equal in magnitude to that of the Elephant, and as massive in its proportions; for, being a vegetable feeder, a large development of the abdominal region may be inferred. Its limbs must have been of a proportionate size to sustain so enormous a bulk; one of the thigh-bones (in the British Museum), if covered with muscles and integuments of suitable proportions, would form a limb seven feet in circumference. The hinder extremities, in all probability, presented the unwieldy contour of those of the hippopotamus or rhinoceros, and were supported by very strong short feet, the toes of which were armed with claws like those of certain turtles. The fore-legs appear to have been less bulky, and were furnished with hooked claws resembling the ungueal phalanges of the Iguana. The teeth demonstrate the nature of the food required for the support of this herbivorous reptile, and the power of mastication it enjoyed; and the ferns, cycadeous plants, and coniferous trees, with which its remains are associated, indicate the flora adapted for its sustenance. But the physiognomy of this creature, from the peculiar modification of the skull and jaws, required for the attachment and support of the powerful muscles necessary for the trituration of tough vegetable substances, must have differed entirely from that of all known saurians.

The length of the Iguanodon has been variously estimated;

the difference in the computation depending chiefly on the extent assigned to the tail, which in the Iguana and many other lizards is much longer than the body. If the tail of the fossil reptile was slender, and of the same relative proportions as in the Iguana, the largest individual would be fifty or sixty feet long ; but it is more probable, and in fact almost certain, from the shortness of the bodies of the caudal vertebræ, that the tail was short, and flattened in a vertical direction, as in certain living reptiles—for example, the *Doryphorus ;* in that case, the length of a full-grown Iguanodon would but little exceed thirty feet.*

From what has been advanced we may conclude, that the Iguanodon was a gigantic but inoffensive herbivorous reptile, which lived on the ferns, cycadeæ, and coniferæ, that constituted the flora of the country of the Wealden, of which it appears to have been the principal inhabitant.

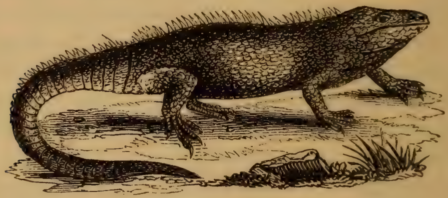
43. The Hylæosaurus, or *Wealden Lizard ;* Plate IV. —This is another reptile of the Wealden, possessing the same remarkable construction of the sacrum as the Iguanodon, and which I have distinguished by a name indicative of the geological formation in which its remains occur. The first and most important specimen of the Hylæosaurus was discovered in the summer of 1832, under the following circumstances.

Upon visiting a quarry in Tilgate Forest, which had yielded many organic remains, I perceived in some fragments of a large mass of calciferous grit, which had recently been broken up and thrown on the road-side, traces of numerous pieces of bones. I therefore collected all the recognizable portions of the block, and had them conveyed to my residence. Having cemented the fragments together, and chiselled off the stone in which the bones were imbedded, so far as their brittle state would admit, I succeeded, after much labour, in developing a considerable portion of

* Medals of Creation, p. 751.

the skeleton of a reptile, in which are blended the osteological characters of the crocodiles with those of the lizards.

The vertebræ of the neck (*Pl.* IV. 2), several of the back (3, 3), many ribs (4, 4), the two coracoid bones (7, 7), and scapulæ (8, 8), remain not far removed from their natural order of juxtaposition. There are also several dermal or skin bones, which supported the thick scales or scutes; of these the most extraordinary are certain large angular bones (5, 5, 6, 6), which lie in the direction of the vertebral column, and appear to have extended along the back, like the horny serrated fringe in the Iguana. Many other existing lizards have appendages of this kind, which



LIGN. 108.—CYCLURA CARINATA.
(*A recent Lizard, allied to the Iguana. Dr. Harlan.*)*

in some genera are largely developed; as for example in the *Cyclura* (*Lign.* 108).†

There are several detached bones dispersed in the block

* Medical and Physical Researches, by R. Harlan, M.D. F.G.S. 8vo. Philadelphia, 1835.

† Professor Owen doubts the correctness of this interpretation, and is disposed to regard these angular spines as abdominal ribs. He particularly dwells on the unsymmetrical form of some of these bodies, but which appears to me to have arisen from compression. The other objections are not more valid; and as it is now ascertained that the internal structure of these spines is identical with that peculiar modification known only in the true dermal bones, the evidence is in favour of this view of the subject.

of stone ; numerous vegetable remains, and carpolithes, or seed-vessels of the Clathraria (*ante*, p. 399), were detected in reducing the size of the mass.*

I subsequently obtained many bones of this reptile from a bed of clay near Crawley ; and a most interesting specimen of part of the vertebral column, comprising nearly thirty dorsal and caudal vertebræ, with many dermal bones and spines, ribs, &c.

Dermal bones and spines.† The structure of the dermal bones is very peculiar, and closely resembles that of the ligamentous fibres of the *corium*, or skin, and seems to have resulted from an ossified condition of the dermal integument.‡ Upon inspecting the surface exposed by a transverse fracture of the oval scutes, minute osseous spiculæ, decussating each other at right angles, are visible to the naked eye ; and under the microscope, the same arrangement is found to prevail in the minutest bony fibres ; the medullary canals have fine lines radiating from them.

I have very lately been able to ascertain that the same internal structure characterizes the spinous bones (*Plate* IV. 5, 6) ; and this fact tends to confirm my opinion, that they are also ossified dermal processes, which formed a longitudinal crest along the back of the animal.§

* For further particulars see my Geology of the South-East of England, p. 316. Pl. V. of that work is an excellent lithograph of this specimen, by Mr. Pollard, of Brighton.

† Medals of Creation, vol. ii. p. 704.

‡ See my Memoir on the Fossil Reptiles discovered in Tilgate Forest, Philos. Trans. for 1841.

§ The following are Professor Owen's remarks on the dermal scutes:—
" By the kindness of Dr. Mantell I have been favoured with the means of submitting the structure of a dermal scute to microscopical examination. The medullary canals, which are stained brown, as if with the hematosine of the old reptile, differ from those of ordinary bone, in the paucity or absence of concentric layers. They are situated in the interspaces of straight, opaque, decussated filaments, which frequently seem to be cut short off, close to the medullary canals.

The Hylæosaurus was probably a terrestrial herbivorous reptile, between twenty and thirty feet in length. The modification of form in the bones composing the sternal arch—in which a coracoid of the lacertian type is united with a scapula like that of the crocodiles—together with other osteological peculiarities, and the largely developed dermal processes, all combine to point out the original as a most extraordinary type of reptilian organization.

LIGN. 109.
TOOTH OF THE HYLÆOSAURUS?
From Tilgate Forest; natural size.

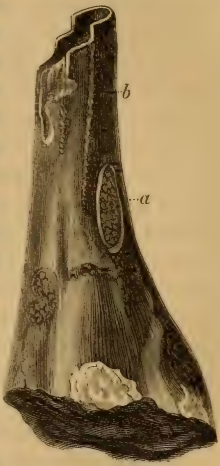
As no portion of the jaw has been found, the characters of the dental organs are unknown; but I have long considered the teeth before us (*Lign.* 109) as probably referable to the Hylæosaurus. They are generally from one inch to one and a half inch long, with a cylindrical shank, which enlarges into an obtuse, lanceolate crown, convex in front, and depressed behind; the margins of the crown are invariably worn, as if by use: the internal structure consists of firm dentine, with extremely minute tubes radiating from the centre to the periphery of the tooth, which has a thick coat of enamel.*

44. PTERODACTYLES OF THE WEALDEN.—In the Wealden, numerous fragments of bones, which from their tenuity

Very fine lines may be observed to radiate from some of the medullary canals; irregularly shaped, oblong, and angular radiated cells, are scattered through most parts of the osseous tissue, but they present less uniformity of size than do the Purkinjian cells in ordinary bone. The most striking characteristics of the dermal bone, are the long, straight, spicular fibres which traverse it, and decussate each other in all directions, representing, as it seems, the ossified ligamentous fibres of the original corium."—*British Association Reports,* for 1841, p. 115. This description will equally apply to the internal structure of the dorsal spines; but the latter has not yet been seen by Professor Owen, as I have but very recently obtained a specimen for microscopical examination.

* Medals of Creation, vol. ii. p. 737.

must have belonged to animals capable of flight, have been obtained from various localities. Several are figured in my Fossils of Tilgate Forest. The imperfect state of the specimens renders it extremely difficult to determine whether any of these bones belong to a higher order of animals than reptiles—whether, in fact, some of them are not referable to birds. The solution of this problem has long been attempted by a rigorous examination of every specimen; and but a short time since it was supposed that unquestionable relics of birds were among the fossils which I had obtained from the strata of Tilgate Forest; and a supposed tarso-metatarsal bone of a Wader was regarded as affording unequivocal evidence on this point.* Recently, however, the question has been reduced to its former state; for the presumed tarso-metatarsal bone, proves to be a *humerus* or arm-bone; and, as Professor Owen now believes, of an undoubted Pterodactyle; an opinion which Mr. Bowerbank states is confirmed by the microscopical examination of its internal structure. Be this as it may, we may safely infer that Pterodactyles were comprised in the fauna of the Wealden.



LIGN. 110.—THE DISTAL OR LOWER PORTION OF THE HUMERUS OF AN ANIMAL CAPABLE OF FLIGHT.
From the strata of Tilgate Forest.
(*Anterior aspect; nat. size.*)
a, Oval cicatrix indicating the insertion of a powerful muscle.
b, Ridge for the attachment of fasciæ or muscles.

I subjoin a correct representation of the inferior portion of this bone (*Lign.* 110). In my opinion, the upper extremity indicates a more expanded

* See my Memoir on the Bones of Birds discovered in the strata of Tilgate Forest; Geol. Trans. vol. v. New Series, p. 175.

head than is observable in the known humeri of Pterodactyles;* and it appears to me impossible to pronounce, with any certainty, as to the true character of the animal to which it belonged, till other specimens are obtained.†

45. Birds of the Wealden.—In describing the fossil remains of the mammalia of the eocene or ancient tertiary epoch, it was stated that species of several existing genera of birds were contemporaneous with the palæotheria and other extinct pachyderms, but that no vestiges of this class had been found in the chalk, or in strata of an earlier date. In my Fossils of Tilgate Forest, I mentioned, that after selecting from the bones which seemed to belong to animals capable of progression through the air, those which appeared to be referable to the Pterodactyles, several remained which bore so striking a resemblance to those of waders that I ventured to refer them to that order of birds; an opinion which was corroborated by Baron Cuvier, to whom I submitted them on his last visit to England, in 1830. Subsequently, Professor Owen instituted a rigid examination of these bones, and satisfied himself that some of them unquestionably belonged to a species of wading bird.‡ More recently, this distinguished physiologist has seen reason to alter his opinion; and upon finding that the supposed tarso-metatarsal bone is a humerus (*ante*, p. 439), now affirms that all the bones of the wealden referable to flying animals, are reptilian. With the view of determining if possible this difficult problem, Mr. Bowerbank instituted a microscopical investigation of the intimate structure of bone in birds and reptiles; and has commu-

* See Geol. Trans. vol. v. Pl. XIII. *fig.* 3.

† See Prof. Owen on supposed fossil bones of Birds; Geol. Journal, 1846, p. 96; and my remarks in the same work, p. 104, on the Fossil remains of Birds in the Wealden; the figure accompanying my paper is most inaccurately represented by the lignograph.

‡ See Medals of Creation, vol. ii. p. 805.

nicated the result to the Geological Society. This eminent microscopical observer has found a recognizable difference in the form and proportion of the minute cells of the bones, which he believes is constant, and by which the smallest fragment may be referred to its proper class. In *Birds*, under a power of 500 linear, by transmitted light, the cells are found to have a breadth in proportion to their length of from one to four or five; while in *Reptiles* the length exceeds the breadth ten or twelve times. For example:—

In the Albatross, the width of the cell is $\frac{1}{4}$ the length.
— Crocodile — — — $\frac{1}{12}$ —

Applying this test to the supposed bones of birds from the chalk, Mr. Bowerbank finds that the specimens regarded by Professor Owen as belonging to an extinct species of Albatross,* are reptilian; the length of the cells being twelve times that of their width, as in the bones of the cranium, jaws, &c. of an undoubted Pterodactyle (*P. giganteus*) found in the same quarry, and to which he therefore refers them.†

The wealden bones, subjected to the same interrogatory, gave different results. The bone figured *Lign.* 110 has cells of the reptilian type, and is therefore declared by Mr. Bowerbank to be that of a Pterodactyle: while some of the other specimens (especially that examined by Baron Cuvier, and figured in Geol. Trans. vol. v. Pl. XIII. *fig.* 6.) have short elliptical cells as in true birds, and are presumed to belong to that class. At the present time, the question

* Medals of Creation, vol. ii. p. 803.

† I would here remark, that these bones are so extremely *thin*, as to render it most improbable that they could ever have sustained such an instrument of flight, as the powerful wing of the Albatross or of any other bird; their tenuity is in fact such as to point out their adaptation to support an expanded membrane, but not pinions.

as to the existence of warm-blooded animals capable of flight, during the wealden and cretaceous epochs, must, therefore, be regarded as in the same state of uncertainty, as when I first announced the occurrence of the supposed bird's bones in the strata of Tilgate Forest, in 1827. I am, however, inclined to believe, that the presence of birds in the secondary formations, will sooner or later be satisfactorily established; and I would, therefore, retain the name of *Palæornis Cliftii*, (*Medals of Creation*, p. 806,) for the wealden ornitholites.

46. The country of the Iguanodon.—By this survey of the strata and organic remains of the Wealden, we have acquired data from which, by the principles of induction already explained (p. 367), we may obtain secure conclusions as to the nature of the country whence those spoils were derived, of the animals by which it was inhabited, and of the vegetables that grew upon its surface. Whether that country was an island or a continent cannot be determined; but that it was diversified by hills and valleys, and irrigated by streams and rivers, and enjoyed a climate of a higher temperature than any part of modern Europe, is most evident. Arborescent ferns, palms, coniferous trees, and cycadeous plants, constituted its groves and forests, and delicate ferns the vegetable clothing of its soil; and in its fens and marshes the equiseta, and plants of a like nature, prevailed. Its principal herbivorous quadruped was the enormous lizard, the Iguanodon; its carnivora, the Megalosaurus and other predaceous reptiles; crocodiles and turtles frequented its rivers, and deposited their eggs on the banks and shoals; and its waters teemed with fishes, mollusca and crustaceans. That the soil was of a sandy nature on the hills and plains, and argillaceous in the lowlands and marshes, may be inferred from the vegetable remains, and the lithological character of the strata in which they are imbedded. Some inferences relating to

the prevailing atmospheric condition of the country may also be drawn from the undulated surfaces of the sandstones, and from the fossil trees. In the former we have proof, that when the land of reptiles existed, the water was rippled by the breezes, which then, as now, varied in intensity and direction in a brief space; by the latter, that in certain situations the wind blew from a particular quarter for a great part of the year, and that the mean annual temperature was as variable as in modern times. From what has been advanced, it must not, however, be supposed, that the country of the Iguanodon occupied the site of the south-east of England; and that the animals and terrestrial plants of the Wealden, lived and died near the spot where their relics are entombed. For, with the exception of the shells and crustaceans, which probably inhabited the delta, all the fossil remains bear marks of having been transported from a great distance. But though three-fourths of the bones we discover have been broken and rolled,—the teeth detached from their sockets,—the vertebræ and bones of the extremities, with but very few exceptions, disjointed, and scattered here and there,—the stems and branches of the trees torn to pieces, and deprived of their foliage,—there is no intermixture of sea-shells, nor of beach or shingle; these remains have been subjected to abrasion from river currents, but not to attrition from the waves of the ocean. The gigantic limbs of the large reptiles could not have been dissevered from their sockets without great violence, except by the decomposition of their tendons from long maceration in water; and if the latter had been the sole cause, we should not find the bones broken and separated, but lying more or less in juxtaposition, like the skeletons of the Plesiosauri in the Lias. The condition in which these fossils occur, proves that they were floated down the river with the rafts of trees, and other spoils of the land, till, arrested in their progress, they sank down, and became imbedded. The phenomena here contemplated cannot, I conceive, be satisfactorily explained upon any other grounds ; and the source of the mighty stream which flowed through the country of the Iguanodon must, therefore, like that of the Mississippi, have been hundreds, perhaps thousands, of miles distant, from the delta accumulated in the course of ages at its mouth.

Such was the country of the Iguanodon—a country, which language can but feebly portray, but which the magic pencil of a Martin, by the aid of geological research, has rescued from the oblivion of the past, and placed before us in all the hues of nature, with its appalling dragon-forms, its forests of palms and tree-ferns, and the luxuriant vegetation of a tropical clime.*

47. SEQUENCE OF GEOLOGICAL CHANGES.—Let us now review the sequence of those stupendous changes, of which our examination of the geological phenomena of the south-east of England has afforded such incontrovertible evidence. From the facts brought before us, we learn that at a period incalculably remote, there existed in the northern hemisphere an extensive island or continent, possessing a climate of such a temperature, that its surface was clothed with coniferous trees, arborescent ferns, and plants allied to the Cycas and Zamia ; and that the ocean which washed its shores was inhabited by turtles, and marine lizards of extinct genera. This country suffered a partial subsidence, which was effected so tranquilly, that many of the trees retained their erect position, and the cycadeous plants, and a considerable layer of the vegetable mould in which they grew, remained undisturbed. In this state an inundation of fresh water covered the country and its forests, and deposited upon the soil and around the trees a calcareous mud,

* See the Frontispiece; an engraving on steel, from an original painting by John Martin, Esq., K. L.

which was gradually consolidated into limestone; thermal streams, holding flint in solution, percolated the mass, and silicified the submerged trees and plants.

A further subsidence took place, floods of fresh water overwhelmed the petrified forest, and heaped upon it accumulations of detritus, which the streams and rivers had transported from the land. The country traversed by the rivers, like that of the submerged forest, enjoyed a tropical climate, and was clothed with palms, arborescent ferns, and cycadeæ; it was tenanted by gigantic herbivorous and carnivorous reptiles, and its waters abounded in turtles, and various kinds of fishes, crustaceans and mollusca. The bones of the reptiles, the teeth and scales of the fishes, and the stems, leaves, and seed-vessels of the trees and plants, were brought down by the streams, and imbedded in the mud of the delta, beneath which the petrified forest was now buried.

This state continued for an indefinite period—another change took place—the Country of Reptiles with its inhabitants was swept away, and the delta, and the fossil trees with the marine strata on which they grew, subsided to a great depth, and formed part of the bottom of a profound ocean; the waters of which teemed with numberless zoophytes, shells, and fishes, of species long since extinct. Periodical intrusions of thermal streams charged with silex, gave rise to layers and veins of nodular and tabular flint, and occasioned the silicification of the organic remains subjected to their influence.

This epoch, which was of long duration, was succeeded by elevatory movements, by which the bottom of the deep was broken up, and large areas were slowly upheaved; and as the elevation continued, the deposits which had accumulated in the depths of the ocean approached the surface, and were exposed to the action of the waves. These masses of cretaceous strata now began to suffer destruction, and the delta of the Country of the Iguanodon gradually emerged above the waters ; and finally, the petrified forest of the Oolite rose in the midst of the sea, and became dry land. At length, some portions of the elevated strata attained an altitude of several hundred feet, and a group of islands was formed ; but in the basins or depressions beneath the waters, sediments derived from the disintegration of the sea-cliffs were deposited. Large herbivorous mammalia now inhabited such portions of the former ocean-bed as were covered with vegetation sufficient for their support ; and as these animals died, their bones became enveloped in the accumulations of mud and gravel, which were forming in the bays and estuaries.

This era also passed away—the elevatory movements continued—other masses of the bed of the chalk ocean, and of the wealden strata beneath, became dry land—and at length those more recent deposits containing the remains of the herbivorous mammalia which were the last tenants of the country. The oak, elm, ash, and other trees of modern Europe, now sprang up where the groves of palms and tree-ferns once flourished—the stag, boar, and horse, ranged over the plains in which were entombed the bones of the colossal reptiles—and finally, *Man* appeared, and took possession of the soil.

At the present time, the deposits containing the remains of the mammoth and other extinct mammalia, are the sites of towns and villages, and support busy communities of the human race ; the Huntsman courses, and the Shepherd tends his flocks, on the elevated masses of the bottom of the ancient chalk ocean*—the Farmer reaps his harvests upon the cultivated soil of the delta of the Country of the Iguanodon†—and the Architect obtains from beneath the petrified forest, the materials with which to construct his temples

* The South Downs.

† The Wealds of Kent and Sussex.

and his palaces :*—while from these various strata, the Geologist gathers together the relics of the beings that lived and died in periods of unfathomable antiquity, and of which the very types have long since been obliterated from the face of the earth, and endeavours by these natural memorials to determine the nature and succession of those physical revolutions, which preceded all human history and tradition.

48. RETROSPECT.—Such is a plain enunciation of the results of our investigations ; but I will embody these inductions in a more impressive form, by employing the metaphor of an Arabian writer, and imagining some higher intelligence from another sphere to describe the physical mutations of which he may be supposed to have taken cognizance, from the period when the forests of Portland were flourishing, to the present time.

"Countless ages ere man was created," he might say, "I visited these regions of the earth, and beheld a beautiful country of vast extent, diversified by hill and dale, with its rivulets, streams, and mighty rivers, flowing through fertile plains. Groves of palms and ferns, and forests of coniferous trees, clothed its surface ; and I saw monsters of the reptile tribe, so huge that nothing among the existing races can compare with them, basking on the banks of its rivers, and roaming through its forests ; while in its fens and marshes, were sporting thousands of crocodiles and turtles. Winged reptiles of strange forms shared with birds the dominion of the air, and the waters teemed with fishes, shells, and crustacea.—And after the lapse of many ages I again visited the earth ; and the country, with its innumerable dragon-forms, and its tropical forests, all had disappeared, and an ocean had usurped their place. And its waters teemed with nautili, ammonites, and other cephalopoda, of races now extinct ; and innumerable fishes and marine reptiles.

* The Isle of Portland.

—And thousands of centuries rolled by, and I returned, and, lo! the ocean was gone, and dry land had again appeared, and it was covered with groves and forests; but these were wholly different in character from those of the vanished Country of the Iguanodon. And I beheld, quietly browsing, herds of deer of enormous size, and groups of elephants, mastodons, and other herbivorous animals of colossal magnitude. And I saw in its rivers and marshes the hippopotamus, tapir, and rhinoceros; and I heard the roar of the lion and the tiger, and the yell of the hyena and the bear.—And another epoch passed away, and I came again to the scene of my former contemplations; and all the mighty forms which I had left had disappeared, the face of the country no longer presented the same aspect: it was broken into islands, and the bottom of the sea had become dry land, and what before was dry land had sunk beneath the waves. Herds of deer were still to be seen on the plains, with swine, and horses, and oxen; and bears and wolves in the woods and forests. And I beheld human beings, clad in the skins of animals, and armed with clubs and spears; and they had formed themselves habitations in caves, constructed huts for shelter, and inclosed pastures for cattle, and were endeavouring to cultivate the soil.—And a thousand years elapsed, and I revisited the country, and a village had been built upon the sea-shore, and its inhabitants supported themselves by fishing; and they had erected a temple on the neighbouring hill, and dedicated it to their patron saint. And the adjacent country was studded with towns and villages; and the downs were covered with flocks, and the valleys with herds, and the corn-fields and pastures were in a high state of cultivation, denoting an industrious and peaceful community.—And lastly, after an interval of many centuries, I arrived once more, and the village was swept away, and its site covered by the waves; but in the valley and on the hills above the cliffs a beautiful city appeared ;* with its palaces, its temples, and its thousand edifices, and its streets teeming with a busy population in the highest state of civilization ; the resort of the nobles of the land, the residence of the monarch of a mighty empire."†

---

* Brighton.

† The concluding portion of these remarks refers to the changes that have taken place on the Sussex coast, during the historical era. Before the Conquest, the greater part of the then little fishing town of Brighthelmston (*Brighthelm's-town*), or Brighton, was situated below the cliffs, on a terrace of beach and sand, now covered by the waves. The Church, dedicated to St. Nicholas, the patron saint of fishermen, was placed on an eminence, that it might serve as a land-mark. The inroads of the sea led to the erection of buildings on the high ground, and their progressive encroachment gradually diminished the area of the ancient town, till at length a sudden inundation, but little more than a century ago, swept away the houses, fortifications, and inclosures that remained.[a] The sea has, therefore, only resumed its former position at the base of the cliffs; the site of the old town having been an ancient bed of shingle, abandoned for ages by the ocean, perhaps contemporaneously with the retreat of its waters from the valley of the Ouse. Should the advancement of the sea be progressive, Lewes Levels (*ante*, p. 61) may again become an estuary, and the town of the *Cliff*, and the hamlet of *Landport*, regain the characters from which their names were derived. See *A Day's Ramble in and about the ancient town of Lewes :* by the Author. 1846.

---

[a] Illustrations of the Geology of Sussex, p. 292. Geology of the South-East of England, p. 23. Dallaway's Western Sussex, vol. i. p. 55.

APPENDIX.

SUPPLEMENTARY NOTES.

A. *Page* 41.—The surface of the moon.—The moon is the only planetary body placed sufficiently near us, to have the inequalities of its surface rendered distinctly visible with the telescope. Attendant on the earth, and having nearly the same density, we may reasonably infer that the mineral substances of which it is composed do not differ essentially from those on the surface of our own planet. If, as is most probable, the moon is surrounded by an atmosphere, it must be very clear and low, for it scarcely occasions a sensible refraction of the rays of light when it passes over the fixed stars. Many of the dark parts of the moon, particularly the part called *mare crisium,* appear to be covered with a fluid, which is probably more transparent than water, as the forms of the rocks and craters are seen beneath it, but not so distinctly as in the lighter parts of the moon's surface. To examine the moon with a reference to its external structure, the defining power of the telescope should be of the first quality, sufficient to show the projections of the outer illuminated limb, as distinctly as they appear when the moon is passing over the disk of the sun during a solar eclipse. With such a telescope, and a sufficient degree of light and of magnifying power, almost every part of the moon's surface appears to be volcanic, containing craters of enormous magnitude and vast depth: the shelving rocks, and the different internal ridges within them, seem to mark the stations at which the lava has stood and formed a floor during different eruptions; while the cones in some of the craters resemble those formed within modern volcanoes. The largest mountain on the southern limb of the moon, like the largest volcanic cone on the earth, Chimborazo, has no deep crater on its summit. There are indeed the outlines of the crater, but it is nearly filled up; while from the foot of this lunar mountain, streams of lava diverge in different directions, to the distance of six hundred miles. The longest known current of modern lava on the earth is in Iceland, and extends sixty miles; but the volcanoes in that island bear no proportion to those of the moon in magnitude.—*Mr. Bakewell.*

B. *Page* 77.—THE LAKE OF THE SOLFATARA.—"Its temperature was, in the winter, in the warmest parts, above 80 deg. of Fahrenheit, and it appears to be pretty constant; for I have found it to differ a few degrees only, in January, March, May, and the beginning of June; being therefore nearly twenty degrees above the mean temperature of the atmosphere, it must be supplied with heat from a subterraneous source. Kircher has detailed in his *Mundus Subterraneus* various wonders respecting this lake, most of which are unfounded; such as that it is unfathomable, that it has at the bottom the heat of boiling water, and that floating islands rise from the gulf. It must certainly be very difficult, or even impossible to fathom a source which rises with so much violence from a subterraneous excavation; and at a time when chemistry had made small progress, it was easy to mistake the disengagement of carbonic acid for an actual ebullition. The floating islands are real, but neither the Jesuit nor any of the writers who have since described this lake, have had a correct idea of their origin, which is exceedingly curious. The high temperature of this water, and the quantity of carbonic acid that it contains, render it peculiarly fitted to afford a pabulum or nourishment to vegetable life; the banks of travertine are every where covered with reeds, lichens, confervæ, and various kinds of aquatic vegetables. At the same time that the process of vegetable life is going on, the crystallization of the calcareous matter which is every where deposited, in consequence of the escape of carbonic acid, likewise proceeds, and gives a constant milkiness to what from its tint would otherwise be a blue fluid. So rapid is the vegetation, owing to the decomposition of the carbonic acid, that even in winter, masses of confervæ and lichens, mixed with deposited travertine, are constantly detached by the currents of water from the bank, and float down the stream; which being a considerable river, is never without many of these small islands on its surface. They are sometimes only a few inches in size, and composed merely of dark green confervæ, or purple or yellow lichens; but, occasionally, are even several feet in diameter, and contain seeds and various species of common water-plants, which are usually more or less incrusted with marble. There is, I believe, no place in the world where there is a more striking example of the opposition or contrast of the laws of animate and inanimate nature—of the forces of inorganic chemical affinity, and those of the powers of life. Vegetables, in such a temperature, and every where surrounded by food, are produced with a wonderful rapidity; but the crystallizations are formed with equal quickness, and are no sooner produced than they are destroyed together. Notwithstanding the sulphureous exhalations from the lake, the quantity of vegetable matter generated there, and its heat, make it the resort of an infinite variety of insect tribes; and even in the coldest days in winter, numbers of flies may be observed on the vegetables surrounding its banks, or on its floating islands. Their larvæ may also be seen there, sometimes incrusted and entirely destroyed by calcareous matter, as well as the insects themselves; and various species of shell-fish that are found amongst the vegetables which grow and are destroyed in the travertine on its banks. Snipes, ducks, and other water-birds, often visit these lakes, probably attracted by the temperature and the quantity of food in which they abound; but these usually confine themselves to the banks, as the carbonic acid disengaged from the surface would be fatal to them, if they ventured to swim upon it when tranquil. In May 18—, I fixed a stick on a mass of travertine covered by the water, and examined it in the beginning of the April following, for the purpose of determining the nature of the depositions. The water was lower at this time; yet I had some difficulty, by means of a sharp-pointed hammer, in breaking the mass which adhered to the bottom of the stick; it was several inches in thickness. The upper part was a mixture of light tufa and leaves of confervæ; below this was a darker and more compact travertine, containing black and decomposed masses of confervæ; in the inferior part, the travertine was more solid, and of a grey colour, but with cavities which I have no doubt were produced by the decomposition of vegetable matter. I have passed many hours, I may say days, in studying the phenomena of this wonderful lake; it has brought trains of thought into my mind connected with the early changes of our globe; and I have sometimes reasoned from the forms of plants and animals preserved in marble in this thermal source, to the grander depositions in the secondary rocks, where the zoophytes or coral polypes have worked upon a grand scale, and where palms and vegetables, now unknown, are preserved with the remains of crocodiles, turtles, and gigantic extinct saurians, which appear to have belonged to a period when the whole globe possessed a much higher temperature. I have likewise often been led, from the remarkable phenomena surrounding me in that spot, to compare the works of man with those of nature. The baths, erected there nearly twenty centuries ago, present only heaps of ruins, and even the bricks of which they were built, though hardened by fire, are crumbled into dust; whilst the masses of travertine around, though formed by a variable source from the most perishable materials, have hardened by time; and the most perfect remains of the greatest ruins in the eternal city, such as the triumphal arches and the Colosseum, owe their duration to this source.

How marvellous are those laws by which the humblest types of organic existence are preserved, though born amidst the sources of their destruction, and by which a species of immortality is given to generations floating, as it were, like evanescent bubbles on a stream raised from the deepest caverns of the earth, and instantly losing what may be called its spirit in the atmosphere!"—*Sir Humphrey Davy's Last Days of a Philosopher.*

C. *Page* 78.— CAVERNS.—One of the most common appearances in limestone caverns, is the formation of what are called *stalactites,* from a Greek word signifying distillation or dropping. To explain these, a brief description of the mode of their production will be necessary. Whenever water filters through a limestone rock, it dissolves a portion of it; and on reaching any opening, such as a cavern, oozes from the sides or roof, and forms a *drop,* the moisture of which is soon evaporated by the air, and a small circular *plate* of calcareous matter remains; another drop succeeds in the same place, and adds, from the same cause, a fresh coat of incrustation. In time, these successive additions produce a long, irregular, conical projection from the roof, which is continually being increased by the fresh accession of water, loaded with calcareous or chalky matter; this is deposited on the outside of the *stalactite* already formed, and trickling down, adds to its length by subsiding to the point, and evaporating as before; precisely in the same manner as, during frosty weather, icicles, which are *stalactites of ice,* or frozen water, are formed on the edges of the eaves of a roof. When the supply of water holding lime in solution is too rapid to allow of its evaporation at the bottom of the *stalactite,* it drops to the floor of the cave, and drying up gradually, forms, in like manner, a *stalactite* rising upwards from the ground, instead of hanging from the roof; this is called, for the sake of distinction, *stalagmite.*

It frequently happens, where these processes are uninterrupted, that a *stalactite* hanging from the roof, and a *stalagmite* formed immediately under it from the superabundant water, increase till they unite, and thus constitute a natural pillar, apparently supporting the roof of the grotto; it is to the grotesque forms assumed by stalactites, and these natural columns, that caverns owe the interesting appearances, described in such glowing colours by those who witness them for the first time. One of the most beautiful stalactitic caverns in England is at Clapham, near Ingleborough. In the Cheddar Cliffs, Somersetshire, there has lately been discovered a similar cave, richly encrusted with sparry concretions.—*See Medals of Creation*, vol. ii. p. 931.

D. *Page* 78.—Weyer's Cave.—This cave is situated in a ridge of limestone hills, running parallel to the Blue mountains. A narrow and rugged fissure leads to a large cavern, where the most grotesque figures, formed by the percolation of water through beds of limestone present themselves; while the eye, glancing onward, watches the dim and distant glimmers of the lights of the guides—some in the recess below, and others in the galleries above. Passing from these recesses, the passage conducts to a flight of steps that leads into a large cavern of irregular form, and of great beauty. Its dimensions are about thirty feet by fifty. Here the incrustations hang just like a sheet of water that has been frozen as it fell; there they rise into a beautiful stalactitic pillar, and yonder compose an elevated seat, surrounded by sparry pinnacles. Beyond this room is another, more irregular, but more beautiful; for besides having sparry ornaments in common with the others, the roof overhead is of the most admirable and singular formation. It is entirely covered with *stalactites*, which are suspended from it like inverted pinnacles; and they are of the finest material, and most beautifully shaped and embossed. In another apartment, an immense sheet of transparent *stalactite* which extends from the roof to the floor, emits, when struck, deep and mellow sounds, like those of a muffled drum. Farther on is another vaulted chamber, which is one hundred feet long, thirty-six wide, and twenty-six high. Its walls are filled with grotesque concretions. The effect of the lights placed by the guides at various elevations, and leaving hidden more than they reveal, is extremely fine. At the extremity of another range of apartments, a magnificent hall, two hundred and fifty feet long, and thirty-three feet high, suddenly appears. Here is a splendid sheet of rock-work, running up the centre of the room, and giving it the aspect of two separate and noble galleries; this partition rises twenty feet above the floor, and leaves the fine span of the arched roof untouched.

There is here a beautiful concretion, which has the form and drapery of a gigantic statue; and the whole place is filled with stalagmitical masses of the most varied and grotesque character. The fine perspective of this room, four times the length of an ordinary church, and the amazing vaulted roof spreading overhead, without any support of pillar or column, produce a most striking effect. In another apartment, which has an altitude of fifty feet, there is at one end an elevated recess, ornamented with a group of pendant *stalactites* of unusual size, and singular beauty. They are as large as the pipes of a full-sized organ, and ranged with great regularity; when struck, they emit mellow sounds of various keys, not unlike the tones of musical glasses. Other cavities, profusely studded with sparry incrustations, extend through the limestone rock. The length of this extraordinary group of caverns is not less than one thousand six hundred feet.—*Abridged from "A Narrative of a Visit to the American Churches;" by Drs. Reed and Matheson. See also, an interesting Narrative of "A Tour to the Caves in Virginia," by the late Dr. Harlan, Medical and Physical Researches,* p. 404.

E. *Page* 93.—RECENT FORMATION OF SANDSTONE.—"A sandstone occurs in various parts of the northern coast of Cornwall, which affords a most instructive example of a recent formation; since we here actually detect Nature at work in converting loose sand into solid rock. A very considerable portion of the northern coast of Cornwall is covered with calcareous sand, consisting of minute particles of comminuted shells, which, in some places, has accumulated in quantities so great, as to have formed hills of from forty to sixty feet in elevation. In digging into these sand hills, or upon the occasional removal of some part of them by the winds, the remains of houses may be seen: and in places, where churchyards have been overwhelmed, a great number of human bones may be found. The sand is supposed to have been originally brought from the sea by hurricanes, probably at a remote period. At the present moment, the progress of its incursion is arrested by the growth of the *arundo arenacea.* The sand first appears in a slight but increasing state of aggregation on several parts of the shore in the bay of St. Ives; but, on approaching the Gwythian river, it becomes more extensive and indurated. On the shore opposite Godrevy Island, an immense mass of it occurs, of more than a hundred feet in length, and from ten to twenty in depth, containing entire shells and fragments of clay-slate; it is singular that the whole mass assumes a striking appearance of stratification. In some places it appears that attempts have been made to separate it, probably for the purpose of building, for several old houses in Gwythian are built of it. The rocks in the vicinity of this recent formation in the bay of St. Ives, are greenstone and clay slate, alternating with each other. The clay slate is in a state of rapid decomposition, in consequence of which large masses of the hornblende rock have fallen in various directions, and given a singular character of picturesque rudeness to the scene. This is remarkable in the rocks which constitute Godrevy Island. It is around the promontory of New Kaye, that the most extensive formation of sandstone takes place. Here it may be seen in different stages of induration, from a state in which it is too friable to be detached from the rock upon which it reposes, to a hardness so considerable that it requires a very violent blow from a sledge to break it. Buildings are here constructed of it; the church of Cranstock is entirely built with it; and it is also employed for various articles of domestic and agricultural uses. The geologist who has previously examined the celebrated specimen from Guadaloupe, will be struck with the great analogy which it bears to this formation. Suspecting that masses might be found containing human bones, if a diligent search were made in the vicinity of those cemeteries which have been overwhelmed, I made some investigations in those spots, but, I regret to add, without success. The rocks upon which the sandstone reposes are alternations of clay slate, and slaty limestone. The inclination of the beds is SS.W., and at an angle of 40°. Upon a plane formed by the edges of these strata, lies a horizontal bed of rounded pebbles, cemented together by the sandstone which is deposited immediately above them, forming a bed of from ten to twelve feet in thickness, and containing fragments of slate, and entire shells; and exhibiting the same appearance of stratification as that noticed in St. Ives Bay. Above this sandstone lie immense heaps of drifted sand. But it is on the western side of the promontory of New Kaye, in Fishel Bay, that the geologist will be most struck with this formation; for here no other rock is in sight. The cliffs, which are high, and extend for several miles, are entirely composed of it; they are occasionally intersected by veins and dykes of breccia. In the cavities, calcareous stalactites of rude appearance, opaque, and of a grey colour, hang suspended. The beach is covered with disjointed fragments, which have been detached from the cliffs above, many of which weigh two or three tons."—*From a Memoir by Dr. Paris, in the Transactions of the Royal Geological Society of Cornwall.*

F. *Page* 109.—On the subsidence of the coast at Puzzuoli. *Letter from C. Hullmandel, Esq. to the Author.*—" Most travellers merely pass through Puzzuoli in their way to Baia, and few being acquainted with the Neapolitan dialect have had the opportunities which I enjoyed, of conversing with the natives upon the subject. In the year 1813, I resided for four months in the Capuchin convent of Puzzuoli, which is situated between the road from Naples, and the sea, at the entrance of the town of Puzzuoli. In the Capuchin convents the oldest friar is called '*il molto reverende;*' and the one who then enjoyed the title in this convent was 93 years old. He informed me that when he was a young man, the road from Naples passed on the *seaward side* of the convent; but that from the gradual sinking of the soil, the road was obliged to be altered to its present course.

" While I was staying at the convent, the refectory, as well as the entrance gate, were from six inches to a foot under water, whenever strong westerly winds prevailed so as to cause the waters of the Mediterranean to rise. Thirty years previously, my old informant stated, such an occurrence never took place. In fact, it is not probable that the builder of the convent would have placed the ground-floor so low as to expose it to inundations, as it now is. Moreover, the small wharf at Puzzuoli, like the convent, is constantly under water when westerly winds prevail; here again it is evident that the original constructors of the wharf never intended it to be in this state. These facts appear to prove that the gradual subsidence of the soil has been going on for many years, and is still in actual progress, and corroborate the opinion derived from the appearances observable on the columns of the Temple of Jupiter Serapis, that the country has been subjected to alternate elevations and subsidences."

"*London, November*, 1839."

DESCRIPTION OF THE PLATES

OF

VOLUME I.

DESCRIPTION OF THE FRONTISPIECE.

(*See page* 444.)

A PICTORIAL ILLUSTRATION OF THE COUNTRY OF THE IGUANODON, FROM THE GEOLOGICAL DISCOVERIES OF THE AUTHOR.

BY JOHN MARTIN, ESQ. K.L.

THE mode of induction by which the geologist and comparative anatomist are enabled to ascertain the form and structure of animals and plants which no longer exist on the face of the earth, and even the nature of the countries which they inhabited, is explained in the preceding pages. From the materials furnished by the researches of the Author in the Wealden formation of the south-east of England, the eminent painter of "BELSHAZZAR'S FEAST," (Mr. John Martin,) composed the striking picture that forms the frontispiece of this Work.

The data upon which the restorations are founded are described in the Fourth Lecture, Part II. (see p. 360). The painting represents a country clothed with a tropical vegetation, peopled by colossal reptiles, and traversed by a river, which is seen to empty itself into the sea, in the distance. Oolitic rocks form the heights and cliffs with which the landscape is diversified. The vegetation consists of the trees and plants whose fossil remains have been discovered in Tilgate Forest, namely, arborescent ferns, clathrariæ, and coniferous trees; while the lesser species are distributed over the foreground.

The reptiles comprise the Iguanodon (p. 422), Hylæosaurus (p. 435), Megalosaurus (p. 421), Crocodiles (p. 415), and Turtles (p. 410). An Iguanodon attacked by a Megalosaurus and Crocodile, constitute the principal group; in the middle distance an Iguanodon and Hylæosaurus are preparing for an encounter; a solitary Pterodactyle, or flying reptile (p. 438), with its wings partly expanded, forms a conspicuous object in the foreground; while Tortoises are seen crawling on the banks of the river. Ammonites and other shells of the Portland oolite, which is the foundation rock of the country, are strewn on the shore.

DESCRIPTION OF THE GEOLOGICAL MAP OF ENGLAND.

PLATE I.

THIS map, or rather ground plan, is necessarily on too small a scale to afford more than a very general idea of the geographical distribution of the principal groups of strata over England, in accordance with the chronological synopsis in Lecture III.*

A summary of the general features of the country is given in page 207, which it is unnecessary here to repeat; but it may be interesting to offer a slight sketch of what may be termed the Geology of the shores of England. With this view, if we start on an imaginary cruise from the north, beyond Berwick, and proceed along the eastern, south-eastern, and southern coasts, to the Land's-End, and then sail along the western shores till we reach the Solway Firth, the following geological phenomena will successively be presented.

The border country of England and Scotland consists of *Silurian* deposits, with a tract of *Devonian* north of Berwick, in which fossil fishes have been met with. From Berwick to Shields, the *Carboniferous* system, comprising the *Mountain limestone, Coal,* and *Millstone grits,* forms the Northumberland coast; a few insulated masses of plutonic rocks (*Trap*) appearing here and there; as for example, at Bamborough Castle, and Dunstanborough. From near Tynemouth to Hartlepool, the *Magnesian limestones* of the *Permian* system appear; thence to Redcar, the *Trias* deposits, in which the embouchure of the river Tees is situated, form the shore.

The coast of the north riding of Yorkshire, composed of *Lias* and *Oolite,* is now reached; a tract that includes Whitby, in the neighbourhood of which place are high cliffs of Lias, abounding in fossils of great variety and interest; as for example, Ichthyosauri and other reptiles: jet, wood, and numerous shells. In the continuance of this coast to Scarborough and Speeton, the *Great Oolite, Coral-rag, Oxford clay,* and other members of the Oolite appear, containing organic remains in profusion; and along this shore are exposed the intercalated *fluvio-marine* strata, full of cycadeous plants, ferns, &c. lignite, and coal. Thence to Flamborough Head, the *Greensand, Speeton clay,* and *Red chalk* emerge, and finally, the *White chalk*, of which the high cliffs of the promontory consist. From this part of Yorkshire, the coast boundary is chiefly made up of the alluvial deposits of Holderness; and along the maritime district of Lincolnshire, till we reach Norfolk, of low cliffs, of gravel, and marine detritus; covered in many places by drift, containing mammalian remains. The chalk range of Norfolk extends to the sea on the north, from Thornham to Blakeney; and at Cromer is capped by mammaliferous Crag.

The tertiary strata of Norfolk are for the most part obscured along the coast by drift and alluvial debris, in which great numbers of the teeth and bones of mammoths, and other extinct mammalia, have been discovered. At Happisburg, numerous bones of elephants have been met with; in the Crag cliffs near Southwold, the teeth of *Mastodon longirostris* have been found.

---

* For convenience the Silurian and Cumbrian deposits are denoted by the same number (8) and colour.

Plate 1.

GEOLOGICAL MAP OF ENGLAND

G.A.M. del. Jos. Dinkel lith.

At Aldborough, the *Coralline Crag* appears inland; and in the cliffs at Bawdsey and Felixstow, the *Red Crag** is seen overlying the *London clay;* and a fine section is exhibited at Walton Naze, south of Harwich. At Clacton, there is a post-tertiary deposit, containing freshwater shells, and mammalian remains.

We now approach the embouchure of the Thames, which lies in a trough of London or eocene clay; certain localities, as the Isle of Sheppey, the cliffs in Herne Bay, &c. abounding in fruits and other vegetable remains, which are associated with marine shells, and bones of mammalia, birds, reptiles, scales and teeth of fishes, &c.

The North Foreland of the chalk range of Kent is next passed, the coast being flanked by vertical cliffs of the Cretaceous formation to Dover. The grey chalk appears at the base of Shakspeare's Cliff; and the lower members of the series, the *Firestone, Galt,* and *Greensand,* at Folkstone and Hythe; the cliffs in Eastware Bay abound in Galt fossils.

The low alluvial district of Romney marshes now skirts the sea-shore, to near Winchelsea; this town and Rye being situated on mounds of Wealden strata, that rise through the silt of the surrounding marsh lands.

We now pass along the eastern extension of the Wealden denudation on the Sussex coast; the Wealden sands and sandstones, with alternating clays and shales, constituting the range of cliffs that stretches, with but little interruption, from the east of Hastings to Bexhill; and in which the usual fossils occur in considerable abundance.

Accumulations of shingle now bound the bay formed by Pevensey levels, which is guarded by numerous martello towers, and the Wealden strata are wholly concealed. Near Southbourn, on the north of the South Downs, the Greensand, Galt, and Firestone, reappear; and are surmounted by the White chalk, which abruptly rises into the promontory of Beachy Head. A bold line of chalk cliffs, interrupted only by a few valleys, through which the rivers from the interior discharge their waters into the sea, now stretches along the coast towards Brighton; where, to the extent of three or four miles, the cliffs consist of detritus, containing bones of elephants, whales, horses, deer, and other mammalia. At the embouchure of the river Ouse, which flows into the sea from Lewes, the chalk cliffs forming the western headland of Newhaven harbour, are capped by tertiary eocene strata.

To the west of Brighton, the coast is for the most part low; the foundation rock of the district, the chalk, seldom rising into view; and thick beds of alluvial covering, with eocene strata beneath, form the tract on the south of the Downs, through western Sussex, and the adjacent maritime district of Hampshire.

The Sussex coast at Bognor, is skirted by a few low rocks of calciferous sandstone, abounding in eocene tertiary shells: and in Bracklesham bay, a bank of London clay and sand has yielded numerous organic remains of great interest.

We now sail round the eastern termination of the Isle of Wight, and perceive on the north the tertiary strata in Whitecliff bay, abutting against the vertical chalk of Culver Cliff. Rounding the promontory, we enter Sandown bay, where the Wealden beds rise in an anticlinal position from under the cretaceous strata. The ruinous chalk escarpment of the Undercliff is next passed, and we enter another bay of the Wealden, at Brixton, Brook, and Compton; and again meet with bold precipices of chalk at Freshwater Gate and the Needles; and vertical eocene strata in Alum Bay.

Pursuing our westward course, we see the distant coast of Hampshire, by Hord-

---

* Through an oversight, the term "*Norfolk*" has been affixed as a synonym to the *Red Crag*, in page 224; but Mr. Charlesworth informs me, that neither the *Red* nor *Coralline Crag* occurs in any part of the county of Norfolk.

well and Christchurch, formed of freshwater and marine tertiary deposits; and entering Studland Bay, perceive the vertical chalk cliffs of Handfast point. Coasting along the Isle of Purbeck, the different members of the cretaceous and wealden formations are seen in various parts of this sinuous and indented line of coast; in some places forming the entire cliffs; in others surmounting the Kimmeridge clay and Portland oolite; and we pass by the little Coves in the south-west of the Island, in which the strata of the Chalk, Wealden, and Oolite, appear in a vertical position.*

Rounding the insulated mass of *Oolite* that forms the Isle of Portland, we reach the Dorsetshire coast, which is here composed of beds of the *Inferior oolite.* These deposits are succeeded near Lyme Regis by cliffs of *Lias;* which the researches of the late Miss Mary Anning, and Mr. Hawkins, have rendered so celebrated; the remains of Ichthyosauri, Plesiosauri, and other reptiles, with numerous shells, crinoidea, and plants, excelling in beauty and variety, those of any other English locality.

The Lias is succeeded on the west by Triassic strata; and these, after a short interruption of greensand, reappear and continue by Sidmouth, Exmouth and Teignmouth to near Babbicombe, where the *Devonian*, or *Old Red deposits*, first emerge: beautiful coralline marbles are quarried near Babbicombe.

The coasts of Devonshire and Cornwall, with but few interruptions, are made up of the different members of the Devonian system; Silurian strata occurring in a few localities. *Mica* and *Chlorite schists*, form the promontory at Start Point; *Serpentine* and *Diallage rock;* the Lizard; and *Granite*, the Land's-End. From Plymouth to Falmouth is the grand region of copper ores; the country consisting of slaty rocks (termed *Killas)*, and limestones, traversed by porphyritic (provincially called *Elvan*) dikes, with protrusions of granitic rocks. Intrusions of *Trap* are frequent all over this part of England; at St. Ives, the cliffs are composed of this igneous product.

The western shores of Cornwall present similar phenomena; and throughout this sea-coast, elevated terraces of beach or shingle are numerous, proving the frequent alteration in the relative level of sea and land, which have here taken place.

Along the west coast of Devonshire, beds of the Carboniferous system appear; the shales are often highly contorted, and occur in the state of indurated slate, provincially called *culm:* they contain shells, and many of the usual species of coal plants.

In north Devonshire, the Devonian system reappears; and at Ilfracombe there are beds of limestone and calcareous slates, full of shells and corals. If we pass up the Bristol Channel, as far as Watchet, we find a line of Lias cliffs, abounding in shells and reptilian remains.

But it would extend this notice to too great a length, were I to point out every interesting locality within view, in our voyage along the western coasts of England: it must, therefore, suffice to mention only the most striking geological phenomena.

Crossing to the opposite Welsh coast, mountain limestone, capped by Lias, appears at Nash Point, and near Dunraven; and in Swansea and Carmarthen bays, we perceive the great South-Wales coal-measures fully developed; the promontory of Worm's Head, which lies between the bays, being composed of Devonian strata and Mountain limestone. Near Tenby, the cliffs are formed of carboniferous deposits, very much contorted: and beyond, at St. Goven's Head, beds of mountain

* The details of the geology of the coasts of the Isle of Wight and Purbeck, are given in my Geology of the Isle of Wight.

limestone appear under similar conditions. In Milford Haven, which is chiefly flanked by Devonian rocks, Silurian deposits appear near St. Ann's Head; and there are numerous isolated masses of Trap: Ramsey Island, and St. David's Head, also consist of these igneous rocks.

We now enter Cardigan Bay, which is formed in the lower division of the Silurian system. The strata consist for the most part of slates with characteristic fossils, which are associated with contemporaneous and intrusive igneous rocks. Mica and chlorite schists, form the cliffs on the southern headland of Caernarvon Bay, and similar rocks occur in the Menai Straits, and at Holyhead; with interspersions of Devonian, Silurian, and Carboniferous strata. Along the coast of Denbighshire, the Upper Silurian strata reach the coast, and are succeeded by Carboniferous and Triassic deposits.

Crossing the embouchure of the river Dee, which is situated in the Coal-measures, the Triassic system of Cheshire appears at Birkenhead. Marine detritus and alluvium obscure the regular strata along this part of the Lancashire coast; until beyond Lancaster Bay, where Upper and Lower Silurian strata, and Mountain limestone appear.

At St. Bees Head, the coast exhibits coal-measures, covered by *Permian* deposits; and at Whitehaven and Workington, the sea-shores are entirely composed of carboniferous strata, the beds of coal being worked far under the sea. At Maryport, the magnesian limestone of the Permian system forms the cliffs. We now enter the Solway Firth, and terminate this rapid sketch of the geological phenomena exhibited by the coasts of England.

DESCRIPTION OF PLATE II.

EXTINCT VOLCANOES OF AUVERGNE.

I. Profile of Mont Dore, as seen from a distance; with a plan of the crater of the mountain: see page 271.

II. Part of the sc n chain of Puys; exhibiting the broken craters of Chaumont, each with a current of lava issuing from its base: Mont Dome is seen in the distance: see page 268.

III. View of the Environs of Clermont, from the Puy Girou.

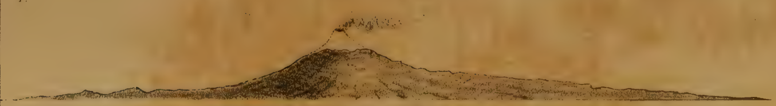
In the foreground is a basaltic peak, on the summit of which is the Castle of Montrognon. The town of Clermont is seen in the valley immediately beyond; and Montferrand in the plain on the right.

The dark horizontal lines indicate the basaltic platform which caps the summits of the hills of fresh-water limestone. These beds of basalt are between 300 and 400 feet in thickness, and are spread over limestone strata, which, together with the basalt, were once continuous, but have since been eroded, and the detritus carried away by alluvial action; see page 276.

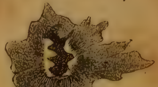
The remote distance is the granitic escarpment, forming part of the boundary of the plain of Auvergne; see page 270.

Plate II.

I.



PROFILE OF MONT DORE

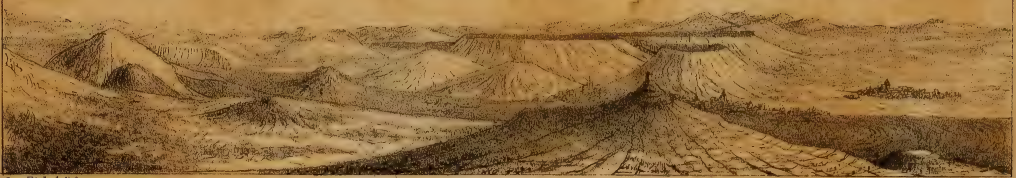


Plan of the Crater

II

VIEW OF THE CHAIN OF PUYS; MONT DOME IN THE DISTANCE.

III



Jos: Dinkel. lith

Printed by Hullmandel & Walton.

VIEW OF THE ENVIRONS OF CLERMONT, FROM THE PUY GIROU.

DESCRIPTION OF PLATE III.

THE REMAINS OF AN IGUANODON; FROM THE KENTISH RAG, NEAR MAIDSTONE.

Described pp. 427—429.

(Length of the original eight feet.)

1, 2. The right and left thigh-bone, or *femur*.
3. A leg-bone, or *tibia*.
4, 4, 4. Bones of the toes (*metatarsal* and *phalangeal*) of the hind feet.
5. *Ungueal*, or claw-bone of the hind-foot.
6. Two *metacarpal*, or first finger bones of the fore-foot.
7. One of the bones (*radius*) of the fore-arm.
8, 8, 8. Vertebræ of the back and tail: in the upper part of the specimen eight vertebræ remain in a consecutive series.
9, 9, 9. Ribs; some nearly entire, others broken.
10, 10. Two clavicles, or collar-bones.
11, 11. Two bones of the pelvis (*iliac bones*).
12. A *chevron-bone*, or inferior spinous process of the tail.

Plate III

J. Dinkel del. et lith.

Hullmandel & Walton Lithographers.

PART OF THE SKELETON OF AN IGUANODON
FROM A QUARRY NEAR MAIDSTONE

[illegible]

DESCRIPTION OF PLATE IV.

REMAINS OF THE HYLÆOSAURUS, DISCOVERED IN TILGATE FOREST.

Described pp. 435—438.

(The original is four and a half feet in length.*)

This plate represents the highly interesting specimen discovered in Tilgate Forest, in the summer of 1832; it consists of the anterior portion of a skeleton of the *Hylæosaurus*, or Fossil Lizard of the Weald, lying on the back; the anterior aspect of the bones is therefore seen in this view.

1. Portion of the base of the cranium.
2. Vertebræ of the neck, or *cervical*.
3. Vertebræ of the back, or *dorsal*.
4. Ribs, for the most part perfect, and but little removed from their articulation with the vertebræ.

5, 5, 5. Dermal spines.

6, 6, 6. Three very large dermal spinous processes: each 15 inches in length, (p. 437.)

7, 7. Two *coracoid* bones (belonging to the chest).

8, 8. The two scapulæ.

9. The glenoid cavity, or socket for the head of the arm-bone, formed by the union of the coracoid and scapula.
10. Detached bones.

---

* By mistake, the lithographer has inserted "*inches*," instead of "*feet*," in the title of this plate.

Plate IV.

J. Dinkel del et lith.

Hullmandel & Walton Lithographers.

PART OF THE SKELETON OF A HYLÆOSAURUS: FROM TILGATE FOREST.

(Length of the Specimen 4½ inches.)

ADDENDA TO VOLUME I.

Nebular Theory of the Universe, *page* 41.—The following remarks by one of the most eminent philosophers of our times, are appended, with the view of showing, that although the nebular theory cannot be regarded as having any pretensions to be considered as a philosophical theory supported by direct observations, yet as suggestive of the effects of a law by which it seems propable the sidereal Universe is governed, it is deserving the highest consideration:—"Should the powers of an instrument such as Lord Rosse's telescope, succeed in demonstrating the starry nature of the regular elliptic nebulæ which have hitherto resisted such decomposition, the idea of a *nebulous matter*, in the nature of a shining fluid, or condensible gas, must, of course, cease to rest on any support derived from actual observations in the sidereal heavens, whatever countenance it may still receive in the minds of cosmogonists from the tails and atmospheres of comets, and the zodiacal light in our own system. But though all idea of its ever being given to mortal eye, to view aught that can be regarded as an outstanding portion of primeval chaos, be dissipated, it will by no means have been even then demonstrated that among those stars so confusedly scattered, no aggregating powers are in action, tending to draw them into groups, and insulate them from neighbouring clusters; and, speaking from my own impression, I should say, that in the structure of the Magellanic Clouds, it is really difficult not to believe we see distinct evidences of the exercise of such a power.—Much has been said of late of the nebulous hypothesis as a mode of representing the origin of our own planetary system. An idea of Laplace, of which it is impossible to deny the ingenuity, of the successive abandonment of planetary rings, collecting themselves into planets by a revolving mass gradually shrinking in dimensions by the loss of heat, and finally concentrating itself into a sun, has been insisted on with some pertinacity, and supposed to receive almost demonstrative support from considerations to which I shall presently refer. I am by no means disposed to quarrel with the nebulous hypothesis even in this form, as a matter of pure speculation, and without any reference to final causes; but if it is to be regarded as a demonstrated truth, or as receiving the smallest support from any observed numerical relations which actually hold good among the elements of the planetary orbits, I beg leave to demur. If we go on to push its application to that extent, we clearly theorize in advance of all inductive observation."—*Address to the British Association held at Cambridge, in June* 1845; *by Sir J. F. W. Herschel, Bart.*

Olbers on Aerolites, *page* 52.—The statement in the text is erroneous. Olbers expressly comments on the *non-discovery* of meteorolites in tertiary and secondary strata, and inquires whether from the absence of fossil meteoric stones we are to infer that previous to the last and present arrangement of the earth's surface, no Aerolites had fallen upon it; though, according to Schriebers, it is probable that the phenomenon now occurs not less than 700 times annually?—*See Humboldt's Cosmos, translated by Col. Sabine.*

Masses of native iron containing *nickel*, have however been discovered in Northern Asia in an auriferous deposit, at a depth of 40 feet: and also in the Carpathian mountains; and these masses are very like undoubted meteoric stones.

There is a fine collection of Aerolites, admirably arranged by Mr. König, in the gallery of minerals of the British Museum.

Charing Chalk Detritus, *page* 324.—Since this notice was printed, Mr. Harris has favoured me with a more particular description of this interesting deposit. The village of Charing is situated on the bed of detritus, which in many places is twelve feet thick. Mr. Harris has obtained from it most of the species of Foraminifera which occur in the chalk and in the tertiary strata of the Paris Basin. *Cytherinæ* (marine crustaceans allied to the fresh-water Cyprides, *ante*, p. 405,) abound in the detritus, and also in the neighbouring chalk and chalk-marl. From the abundance of small land and fresh-water shells associated with these cretaceous forms, Mr. Harris infers that the neighbouring dry land was clothed with vegetation before this local drift was formed.

INDEX TO VOLUME I.

T.

U.

V.

END OF VOL. I.

WORKS BY DR. MANTELL.

I. THE FOSSILS OF THE SOUTH DOWNS; or, *Illustrations of the Geology of Sussex.* Royal 4to, with 42 Plates, containing several hundred figures of organic remains from the Chalk formation, Map, &c. 1822.

II. THE FOSSILS OF TILGATE FOREST; or, *Illustrations of the Geology of the South-East of England.* Royal 4to, with a Map, Sections, and 20 Plates, comprising nearly 200 figures of Wealden fossils. 1827.

III. THE GEOLOGY OF THE SOUTH-EAST OF ENGLAND. 1 vol. 8vo, with Maps, Plates, and numerous Figures. *Price* 1*l.* 1*s.*

IV. THE MEDALS OF CREATION; or, *First Lessons in Geology and in the Study of Organic Remains.* 2 vols. foolscap 8vo, in cloth, elegant: with coloured Plates, and several hundred Figures of Organic Remains. 1844.

These volumes present a familiar introduction to the study of Organic Remains, and comprise a general view of Fossil Botany and Zoology. They are at once a popular guide and hand-book for the student and amateur collector of fossil remains, and for the reader who may desire a general acquaintance with a science abounding in objects of surpassing interest, and for the *Tourist* who may wish in the course of his travels to employ profitably and agreeably a leisure hour in the various countries he may visit.

V. THOUGHTS ON A PEBBLE; or, a *First Lesson in Geology.* The *Seventh Edition, with eleven additional Illustrations.* In purple cloth, gilt. 1846. *Price* 3*s.*

VI. THOUGHTS ON ANIMALCULES; or, *a Glimpse of the Invisible World of Being revealed by the Microscope.* 1 vol. square 8vo, with 12 coloured Plates, and Wood Engravings. 1846. *Price* 10*s.* 6*d.*

VII. A DAY'S RAMBLE IN AND ABOUT THE ANCIENT TOWN OF LEWES; illustrative of the objects of Historical, Geological, and Antiquarian interest. 1 vol. with Plates. 1846. *Price* 5*s.*

VIII. GEOLOGICAL EXCURSIONS ROUND THE ISLE OF WIGHT, AND ALONG THE ADJACENT COAST OF HAMPSHIRE AND DORSETSHIRE; illustrative of the most interesting geological phenomena, and Organic Remains. 1 vol. with numerous Plates, Sections, coloured Geological Map, &c. 1847. *Price* 12*s.*

*** This Volume is a popular guide to the "beautiful Island," pointing out and explaining the most remarkable localities, and the fossils with which they abound.

Preparing for Publication,

THE PHENOMENA OF THE NERVOUS SYSTEM; or, a *Familiar Exposition of the Nature and Functions of the Nerves;* being the substance of a course of Popular Lectures. In 1 vol. with numerous Illustrations.

R. CLAY, PRINTER, BREAD STREET HILL.